Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the matter of	)	
	)	
The Commission's Notice of Inquiry for the	)	
Establishment of an Interference Temperature	)	ET Docket No. 03-237
Metric to Quantify and Manage Interference	)	
and to Expand Available Unlicensed	)	
Operation in Certain Fixed, Mobile and	)	
Satellite Frequency Bands	)	
	)	
Facilitating Opportunities for Flexible,	)	
Efficient, and Reliable Spectrum Use	)	ET Docket No. 03-108
Employing Cognitive Radio Technologies	)	

COMMENTS OF V-COMM, L.L.C.

Sean Haynberg
Director of RF Technologies

David Stern
Vice President

Dominic Villecco
President

V-COMM, L.L.C.
3 Cedar Brook Drive
Cranbury, NJ 08512
(609) 655-1200

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COMMENTS OF V-COMM, L.L.C.

V-COMM, L.L.C. (V-COMM)[1] submits these comments in response to the Federal Communications Commission's (FCC or Commission) Notice of Inquiry (NOI) seeking comment on the Establishment of an Interference Temperature Metric to Quantify and Manage Interference and to Expand Available Unlicensed Operation in Certain Fixed, Mobile and Satellite Frequency Bands (Interference Temperature NOI, or NOI), and in response to the FCC's Notice of Proposed Rulemaking regarding the "Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies."[2]

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[1] V-COMM, L.L.C. is a wireless telecommunications consulting company with principal members having over 20 years experience in the wireless industry. We have provided our expertise to wireless operators in RF engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. We have extensive industry experience in all CMRS technologies. V-COMM's company information and experiences are highlighted in the report's Appendix, along with biographies of senior members of its engineering team.

[2] The FCC Interference Temperature NOI, ET Docket No. 03-237, was released Nov. 28, 2003; and the FCC NPRM regarding Cognitive Radio Technologies, ET Docket No. 03-108, was released Dec. 30, 2003.

It is V-COMM's intent to address the technical issues associated with the FCC's Interference Temperature NOI and its potential for causing harmful interference to Commercial Mobile Radio Service (CMRS) networks, in the consideration of sharing these licensed spectrum bands with unlicensed opportunistic devices.

V-COMM has been active in evaluating and performing extensive CMRS spectrum noise studies, and interference compatibility tests with spectrum-sharing technologies within Cellular networks.[3] V-COMM has also served as an independent engineering firm with extensive expertise with CMRS technologies and systems, and has performed spectrum noise and interference measurements within CMRS spectrum, and documented these results for consideration of the Commission.[4] Through extensive testing, V-COMM has gained specific knowledge of the compatibility issues associated with spectrum-sharing technologies, and the technologies and systems operating within CMRS spectrum.

V-COMM has reviewed the FCC's Interference Temperature NOI, provided engineering analyses, and prepared this report pursuant to a contract with Cingular Wireless and Verizon Wireless.

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[3] V-COMM has conducted extensive compatibility and interference tests within AT&T Wireless, Cingular, and Verizon Wireless cellular and PCS networks. With the FCC's AirCell spectrum-sharing proceeding (ET 02-86), V-COMM has submitted comprehensive Engineering Reports, filed on April 10, 2003. The AirCell system currently operates under a FCC waiver that allows co-existing within the Cellular spectrum.

[4] V-COMM has also conducted spectrum noise and interference measurements within Cingular and Verizon Wireless cellular and PCS networks. V-COMM submitted the "AMPS Noise Floor Study" within the FCC's AirCell spectrum-sharing proceeding (ET 02-86), as attachments to engineering reports filed on April 10, 2003. V-COMM also submitted the "PCS Noise Floor Study" within the FCC's Spectrum Policy Task Force Report proceeding (SPTF Report) (ET 02-135), filed on Sept. 16, 2003. The FCC's SPTF Report was released on Nov. 25, 2002.

I. INTRODUCTION

The Commission set forth in its NOI a new concept referred to as Interference Temperature. In the NOI, the Commission envisions a new method of assessing and managing interference rather than the current transmitter based approach. This new approach is envisioned to take into account the actual radiofrequency (RF) environment from both transmitter and receivers as well as the cumulative effect of all undesired RF energy in the particular band. Further in the NOI, the Commission states that this new concept "could provide radio service licensees with greater certainty regarding the maximum permissible interference, and greater protections against harmful interference that could be present in the frequency bands in which they operate" (emphasis added).

Additionally, the Commission envisions a "cap" or Interference Temperature limit that would serve as an upper bound in particular bands. If this cap were not reached, other devices, both licensed and unlicensed would have the opportunity to operate in these bands, in an effort to promote more efficient use of spectrum and additional use of radio communications for the American public.

In these comments presented to the Commission, we will address the issues of current spectral efficiency and interference management in CMRS bands. Further, we will outline the advances that have taken place to increase the user density and feature availability in these bands as well as future features and advances that are intended to continue to promote spectrum efficiency and offer additional radio communications to the American public. We will also explain the concept of internal vs. external interference as it relates to CMRS networks.[5]

[5] *Internal* system interference refers to a CMRS system's co-channel and adjacent-channel emissions existing in markets from its base stations and callers, in addition to the background noise levels present.

Finally, we have developed a model that demonstrates the overbuild requirements that would be placed upon CMRS providers should their noise plus interference levels be raised by even relatively low levels.

We respectively offer our comments to the Commission and seek consideration of the information provided herein which is a culmination of extensive industry experience and field studies in actual CMRS network environments.

II. OVERVIEW AND SUMMARY

CMRS spectrum has been and will continue to be one of the most intensively utilized spectrum allocations licensed by the FCC. The Cellular Telecommunications and Internet Association (CTIA) reported approximately 159 million wireless subscribers in the US as of December 2003[6], an increase of 9.7 percent from 2002. Further, the CTIA has reported that the total wireless minutes of use exceeded 800 billion in 2003, an increase of more than 30 percent over 2002. With a US population of approximately 292 million people[7], the wireless penetration rate is nearly 55 percent. Based upon projections provided by wireless industry analysts, and penetration rates achieved in many European countries, it can be expected that the US wireless penetration rate will continue to 70+ percent, possibly even over 100 percent as in some Nordic countries.

The ability to achieve the current growth and market penetration rates is a direct result of the actions of the wireless industry striving to find new ways to add capacity, increase service

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This is the "interference plus noise" of the system, which is also referred to as the system's operating noise or noise floor of the system. *External* system interference refers to transmissions from unlicensed spectrum-sharing devices that are not part of the CMRS system (they are external to the system).

[6] Information from CTIA Semi-annual Wireless Industry Survey.

quality, increase feature availability and address market demand within limited spectrum allocations licensed by the FCC. The industry has developed effective methods and procedures to manage their licensed spectrum, which has ultimately enabled it to achieve the significant gains reported by CTIA. Further, as a result of the FCC's goal of increased competition, additional carriers have come to market in the last 10 years and usage growth per subscriber has outpaced actual subscriber growth (e.g. 10 percent subscriber growth vs. 30 percent usage growth as reported by CTIA). The FCC can allow these growth trends to continue, and therefore provide for the highest utilization of the CMRS spectrum by promoting the industry's current and future technological advances and self management. Allowing opportunistic unlicensed devices access to this CMRS spectrum will prevent the industry from continuing these trends and detract from the utility enjoyed by more than half of the US population.

The CMRS industry has continuously improved spectrum efficiency over the years by lowering signal and noise levels which has resulted in improved coverage for in-building use, capacity to allow more users and higher usage, and improved quality levels, all at the same time. How did this happen? Why did this happen? Because CMRS spectrum is "managed" spectrum. It is controlled by the network operator and is continuously being fine-tuned by engineers. Advanced features and technologies are constantly added to improve efficiencies and handle the growth and the seemingly insatiable market demand. It has evolved due to innovation and primarily operator <u>incentive</u>. The operator has the incentive to improve spectral efficiency because the network will reap the benefits of any such improvement by allowing the operator to increase capacity, quality and coverage – in other words, to grow. Growth is a powerful incentive in a free market economy, because it benefits not only customers but also shareholders.

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[7] Information from US Census web page.

As previously mentioned, plenty of wireless growth opportunity remains in the US marketplace. Continued investment in spectrally efficient advances translates into expanded enjoyment of the inherently beneficial capabilities of wireless service by the American public. If the FCC gives away the benefits (of improved spectrum efficiency) to unlicensed devices, it will greatly reduce the incentive that would exist in a free market for operators to improve systems or invest in new technology and innovations.

Noise levels in CMRS systems have been going down, not up, even though the number of base stations and wireless phones continues to increase. The noise and interference levels have been going down for a variety of reasons including; new technologies, refined system design techniques (e.g. antenna down-tilting, reduced antenna heights, managed transmitter and mobile power control, better system interference management, etc.). With the very low noise conditions existing in CMRS spectrum today (and with trends expecting to lower noise levels further), there is no room for additional easements from unlicensed devices, and any transmissions from unlicensed devices can only lead to an increase in the operating noise floors in these bands, and impede existing and future services in these CMRS spectrum bands. If the FCC establishes an Interference Temperature Cap, this trend will not continue to be improved; rather it will be reversed due to an increase in the noise and interference level, which can disrupt current service.

Figure 1 in the NOI depicts opportunities for unlicensed devices to use spectrum up to a maximum level, implying this will not cause harmful interference to incumbent systems. This is incorrect for the following reasons: (a) Systems are not designed to overcome maximum interference, rather they tolerate it at reduced quality levels for only brief moments of the day (i.e. 10-30 seconds); if all interference were at maximum levels all the time, it would upset the assumptions relied on by network designers for providing quality service and would, as a result, wreak havoc on the network and cause complete system outages in many cases. (b) The FCC proposed to "give away" the "margin" needed for calls to be handled with quality, particularly the in-building calls. This margin is used by the systems, not wasted as the FCC implies, to provide coverage to in-building users (as well as users in other areas with less than ideal signal levels due to factors such as distance, multi-path, or shielding by buildings or terrain). In-building use, in particular, has become a significant characteristic of current wireless usage. We have had the opportunity to review traffic patterns for several of the nationwide wireless carriers and have observed that, as a result calling plans such as free nights and weekends, peak traffic at evening hours (e.g. 9 o'clock p.m.) equal peak traffic at the tradition vehicular traffic hour of 5 o'clock p.m. The aforementioned margin available to the system operators is used to specifically provide capacity in wireless systems and also high speed data for new packet data services offered in all technologies by all carriers. Without this margin, these in-building and high speed data services could no longer be provided by the system.

FCC Interference Temperature and Cognitive Radio Concepts/proposals will increase spectrum noise floors and cause harmful interference. These concepts will result in "false positives" for spectrum sharing devices that will transmit due to incorrect assessments of spectrum availability, as outlined herein. Additionally, as outlined in the Network Impact Study herein, a significant overbuild of sites would be required for network operators to maintain current levels of capacity, reliability, and coverage in the CMRS bands if the FCC permitted the noise floors to increase, even by as little as a 1/3 dB. As demonstrated in our analysis, these networks are very sensitive to incremental increases in the noise floor and the increased capital and operating expenditures required to overcome these increases are substantial, as much as 390 percent. These substantial increases in costs would ultimately impact the American public.

If network deployment and operating costs are increased by the FCC implementing the proposed concepts, it stands to reason that the economic value of CMRS spectrum would decrease. Additional risk would be encountered by operators trying to acquire subscribers in a highly competitive environment, because they would potentially incur much higher costs to serve an increased customer base than at present. Also, the harm to the network, and the operators' substantial investment in facilities relied on by the public, would be permanent by the very nature of unlicensed wireless devices and the inability to control them once released in mass circulation.

If this "established cap" had happened under analog technology years ago, CDMA would never have been commercially deployed, because the rollout of CDMA depended on operators' ability to clear spectrum of uncontrolled sources of interference and operate at levels close to the noise floor. The same can be said about other new technologies moving forward — they won't happen if licensees cannot ensure that there will not be uncontrolled sources of interference. With an unlimited number of sources of unlicensed, uncontrolled interference, there no longer would be an incentive to develop and deploy new technologies and services that rely on centralized control of interference. As a result, the introduction of an interference temperature cap in the CMRS bands could adversely affect providers' willingness or ability to roll out 3G technologies such as EVDO, EVDV, EDGE, and UMTS.

Other technologies on the horizon may not happen either, including interference cancellation, where the system's interference is removed with pattern matching of known characteristics. Unknown characteristics will remain just that, unknown, and therefore would not be removed. In addition, smart antenna systems, smart radio systems, MIMO technologies (Multiple Input Multiple Output antenna systems), super conductor filter/amplifiers systems, and tower-top low noise amplifiers that all offer improvements in spectrum efficiency by lowering the system's noise levels will become ineffective, as well.

Finally, the FCC's definition of harmful interference needs to be updated. The current definition is somewhat arbitrary and very subjective — *e.g.,* what constitutes serious obstructions to service? The current definition does not offer any protection to licensed carriers unless they can demonstrate that the interference is causing serious detrimental harm to their networks. Any new or revised definition should delineate which services and system attributes should be protected and must address effects on network capacity, coverage, and quality of service. The spectrum licensees must know their rights and responsibilities.

III. SPECTRUM NOISE AND INTERFERENCE STUDIES

As many others parties have commented,[8] it is essential for the Commission to understand the current and evolving state of the radio environment before considering rule changes and adopting interference temperature procedures and levels. Also, the Commission should only rely on interference and noise studies that are directly and recently measured by industry accepted procedures, verified by independent parties, and reproducible in subsequent field tests. It is imperative that spectrum noise studies be conducted using standard tests with actual market conditions, and appropriate test equipment and procedures for accurate results to be ascertained. These studies should be performed in accordance with licensed equipment operators and by industry engineers that have experience with wireless technologies deployed in the bands. Studies conducted many years in the past should also not be solely relied upon, as the state of radio environments change with time. The Spectrum Policy Task Force and the FCC's

Technological Advisory Council (TAC) also recommend "the Commission undertake a systematic study of the RF noise floor" in each RF band.[9]

A. Comprehensive Spectrum Noise Studies Show CMRS Operators with Very Low Noise Floors

V-COMM has conducted extensive and comprehensive spectrum noise floor studies in the CMRS spectrum bands. Complete documentation of the test results, test procedures, and technical comments regarding the interpretation of the data are submitted into the Commission's record for consideration and understanding of the radio environment in the CMRS spectrum bands.

These spectrum noise floor studies were conducted in diverse market environments with typical cell site operating conditions for forward and reverse spectrum bands for cellular and PCS networks. The results of these studies indicate very low operating noise floor conditions, and typical operating noise floors that are significantly lower than the maximum level occurring within markets.

The spectrum noise measurements were collected over intervals of time that captured the variation in noise levels occurring. The spectrum noise surveys included dense urban, urban, suburban and rural market environments within CMRS networks employing AMPS and TDMA wireless technologies. The results of these spectrum surveys are representative of typical operating noise floor conditions occurring in CMRS spectrum bands.

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[8] Comments to the FCC submitted in its Spectrum Policy Task Force proceeding (ET 02-135) include Motorola, Cingular and Sprint, on Jan. 27, 2003.

[9] FCC's Spectrum Policy Task Force Report, Pg. 5.

V-COMM has conducted two such comprehensive noise floor studies in CMRS spectrum, within Cingular Wireless' and Verizon Wireless' cellular and PCS networks. Results of these spectrum noise studies are documented in engineering reports, which have been previously submitted to the Commission in other proceedings. The "AMPS Noise Floor Study" was filed in the AirCell proceeding (ET Docket 02-86) on April 10, 2003, and the "PCS Noise Floor Study" was filed in the SPTF proceeding (ET Docket 02-135) on Sept. 16, 2003. Copies of these spectrum noise floor studies are also included in this report as Attachments B and Attachments C, respectively.

The Advanced Mobile Phone System (AMPS) Noise Floor Study was performed in Verizon Wireless' cellular network within the area surrounding the Philadelphia, PA and New Jersey market. A total of eighteen cell sites were included in the cellular noise study, and the sites were located in diverse market environments (dense urban, urban, suburban, and rural). The results show the distribution of operating noise floor levels occurring over a 24-hour period.

These cellular spectrum noise floor studies show very low operating noise floor conditions. The spectrum noise levels were measured from –127 dBm to –119 dBm, with the highest levels for dense urban market base stations, and an overall operating noise floor average of –126 dBm.[10] With these low operating noise floor conditions, CMRS base station equipment serves cellular phone calls to very low levels, with a sufficient margin above this amount for quality service. Based on these results, "toll quality" AMPS calls can maintain service on these

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[10] The results of the cellular noise floor measurements are provided in Table 5.1 of the AMPS Noise Floor Study report (page 16); provided in Attachment B of this report. Section 8.2 of the AMPS Noise Floor Study report also includes the individual and cumulative distributions of the operating noise levels measured for the eighteen cell sites over the 24-hr business day collection period. Measurements were performed with calibrated test equipment employing a resolution bandwidth of 30 kHz, and measure the AMPS cellular system's operating noise and interference levels.

cell sites at very low levels. The minimum "toll quality" call signal level requiring a carrier-to-interference ratio of 17 dB, is –102 to –110 dBm, with an average of –109 dBm.

The cellular system noise levels varied slightly according to the radio environments of the sites. The operating noise floor levels averaged by the environment types were –123 dBm for sites serving dense urban areas, –126 dBm for sites serving urban areas, and –127 dBm for sites serving suburban and rural areas. The operating noise floor levels for the rural and suburban sites indicate similar and very quiet noise conditions. With the current market trends (in-building cell phone users and the maturity of cellular systems), the suburban market noise floors conditions have approached the rural market conditions. These rural and suburban noise floor levels approach the cell site equipment's thermal noise floor level 55% to 98% of time.

This cellular noise study did not include the lowest noise floor base station equipment or radio environments. For example, sites with tower-top low noise amplifiers or super-conducting amplifier/filter systems were not included; nor were "quiet rural" areas included. In the future, these more sensitive radio environments and equipment configurations should be studied as well.

V-COMM has also conducted additional spectrum noise floor studies in Personal Communication Service (PCS) spectrum. The PCS Noise Floor Study includes measurements of system noise and interference levels occurring in the occupied PCS spectrum band licensed to Cingular Wireless in market areas surrounding Philadelphia, PA and Allentown, PA. A total of twelve field locations were included in the study. These locations included a cross-section of environments including urban, suburban and rural types. These locations included a train station, shopping mall, apartment building, office building, two airports and residential homes. The measurements were performed at typical locations where wireless phones are utilized within buildings and outside. Field measurements were performed within the forward-link PCS spectrum and represent the operating system noise and interference levels experienced at the mobile subscriber units. These measurements were recorded over a sufficient period of time to capture variations in the operating noise floor levels.

The PCS noise measurements were conducted within *occupied* PCS spectrum, and include the co-channel and adjacent channel system interference from within the carrier's network, in addition to the background environment noise levels. These occupied spectrum measurements were conducted within the PCS D band, where Cingular Wireless operates using the digital wireless technology Time Division Multiple Access (TDMA, or IS136), having a nominal 30 kHz channel bandwidth.

The PCS spectrum noise studies show very low operating noise floor conditions existing in occupied spectrum bands in these areas. The spectrum noise levels were measured from –123 to –129 dBm, with the higher levels for the urban areas, and an overall operating noise floor average of –128 dBm.[11] For the majority of the field locations, the median and 90% noise floor levels were below the thermal noise floor of typical TDMA subscriber phone equipment, which is below –124 dBm. With these low operating noise conditions, wireless phone service can be maintained to low operating signal levels. In these cases, TDMA phone service can be maintained with operating signals between –104 to –107 dBm (the minimum signal level for

[11] The results of the PCS noise floor measurements are provided in Table 5.1 of the PCS Noise Floor Study report (page 26); provided in Attachment C of this report. Section 8.2 of the PCS Noise Floor Study report includes the individual and cumulative distributions of the operating noise levels measured at the twelve field locations over the collection period. Measurements were performed with calibrated test equipment employing a resolution bandwidth of 30 kHz for the occupied PCS band measurements.

"toll quality" service), with the required carrier-to-interference ratio of 17 dB for TDMA technology and typical phone equipment noise figures of 5 to 8 dB.[12]

The PCS occupied spectrum measurements averaged for the various environments indicate similar median noise floor levels (–128 dBm) for the rural and suburban market environments, with an increase in the urban areas by about 1 dB. At some of the locations the noise levels did not increase above the thermal noise floor of the measurement equipment used, which indicates that the background environmental noise levels occurring in these market areas are not appreciably increased above the thermal noise floor level.[13] At these very low noise floor conditions, wireless carriers can deploy networks without environmental noise encumbering system performance.

B. Interference Temperature Will Not Work in CMRS Spectrum Because of its Very Low Noise Floor Conditions

As indicated in the PCS and cellular spectrum noise studies above, the operating noise floor conditions that exist in these spectrum bands are very low in all market areas. These measurements were performed within mature and optimized cellular and PCS networks, at typical subscriber locations and base stations in urban, suburban and rural market areas. The noise floor conditions are very low for the vast majority of the day, and at these times the wireless networks can fully utilize the spectrum band and provide quality service to its customers.

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[12] In the presence of considerable signal fading, an additional fade margin may be required to maintain quality service.

[13] *I.e.,* the environmental noise levels were within approximately 1 dB of the thermal noise power level (P) computed by P=kTB, where k is Boltzmann's constant, T is the environmental temperature in Kelvin, and B is the bandwidth in Hertz.

These spectrum noise floor levels agree with observations V-COMM has made over the past several years in cellular and PCS spectrum environments. These changes (lowering) in the cellular spectrum operating noise floor can be attributed to a number of factors that have changed over time. Most significantly, these factors include: cellular mobile phones operating at significantly lower power than in earlier years of spectrum use; cellular mobile phone utilization within buildings; improvements in standard cellular base station equipment technology and performance specifications, and other changes attributed to the maturity of cellular market systems.

These changes have occurred because the spectrum is actively "managed" by the licensed network operator, both in real time through standards-based technology-specific techniques (such as dynamic power control, channel assignments, adaptive rate encoding, and frequency hopping), and in basic network design (which periodically improves). This has allowed advances in technology and system design improvements to optimize the use of the spectrum and reduce the noise levels in the band. The following reasons contribute to the low operating noise conditions existing in today's cellular and PCS networks:

1. In-building Wireless Phone Usage – The usage of wireless phones inside buildings has increased dramatically over the past years. The decrease in signal and noise levels for these inside locations are approximately 10 to 30 dB, due to the signal attenuation of the building structure. For these in-building locations, the background noise and system interference levels are decreased for the phones inside these locations as compared to levels outside the building. This allows CMRS phone service to be maintained at lower signal levels as compared to outdoor locations where the noise floor is elevated above indoor locations.
2. Cell Sites Using Panel Sector Antennas – The most common cellular base station antenna configuration today is the 3-sectored panel antenna system. The panel antenna improves the performance of cellular systems by achieving more gain in the intended 120 degree sector

coverage area, and more protection from interference originating from the remaining 240 degrees. This allows the cell site to achieve lower operating noise floor conditions, by minimizing nearby co-channel and adjacent channel interference. The sector antenna's interference plus noise reduction will be in the range of 5 to 30 dB, depending on the antenna's horizontal beam-width pattern. In the past, omni-directional antennas were more common than they are today. Omni-directional antennas have gain in all directions (360 degrees) and consequently experience higher noise floor levels

3. Transmitter Power Control – All CMRS systems today employ Transmitter Power Control (TPC) algorithms with cell site and subscriber terminal equipment. These algorithms improve the performance of CMRS networks by lowering the cell site and mobile phone transmission levels to the minimum levels required to maintain quality calls. This, in turn lowers the operating noise floor throughout the CMRS system. These algorithms are able to lower the signal levels up to 35 dB for TDMA systems, up to 30 dB for GSM systems and up to 73 dB for CDMA systems. By utilizing these control mechanisms based on the received signal strength and call quality level (Bit Error Rate or Frame Error Rate) the system lowers the signals and noise levels occurring in their networks.

4. Network Design Improvements – with dramatic increases in user demand over the years, PCS and cellular networks have evolved to meet this growing demand. These systems have matured their networks and optimized the use of their spectrum through the following changes in network design:

    a. Smaller cell sites with lower antenna elevations (closer to the height of the clutter of trees and buildings) are much more common, especially in urban market areas. This allows the cell site transmitters to operate at lower power levels and thus lowers the operating noise floor of the surrounding area, which increases system capacity. Also, smaller cell sites allow mobile phones to operate at lower power levels, which in turn lower the interference levels received by the co-channel and adjacent channel cell sites.

    b. Cell site antenna down-tilting is also very common in today systems. With antennas in a down-tilted configuration, the CMRS systems can to better control the RF energy being transmitted and received by the cell, which has the effect of lowering operating signals and nose levels in the spectrum band. The down-tilting concept essentially removes "excess" energy from the horizon and helps contain the transmitted energy within the area of service concern.

c. Narrow horizontal beam-width antennas are used to reduce the cell site's interference noise floor, by limiting the interference that can be seen from the edges of the sector antenna. Antennas with horizontal beam-width of 60 to 80 degrees have become more common in mature cellular and PCS networks than 120 degree sector antenna deployment. These narrower beam width antennas offer further improvements over antennas that cover more of the 120 degrees of the respective sector, thereby lowering the operating noise floor level at the mobile phone location (forward-link) and cell site (reverse-link). The concept of using these antenna systems that have horizontal beam widths that are less than the 120 degree area they are intended to serve is essentially the same concept as down-tilting, i.e. removing excess energy from the horizon and focusing only the minimum energy needed to serve the intended area.

d. Underlay/Overlay cells are also utilized in mature market areas to achieve improved system performance with designated channels having lower system interference levels serving calls within the outer-ring coverage areas, and channels with higher noise floor levels serving calls within inner-ring coverage areas. Handoffs are performed between the base station inner-ring and outer-ring serving areas from one channel group to another. This network channel assignment feature allows a CMRS system to provide improved phone service with lower signal levels on channels with less co-channel interference, for the base stations' outer-ring service areas. This allows noise floor conditions to be lowered for channels designated to outer-ring serving areas, which improves wireless service on channels where it's needed most.

e. Advancements in technology have also improved and lowered the noise levels in the spectrum bands. For example, advanced power control algorithms, adaptive rate vocoders, discontinuous transmission, frequency hopping and improved antenna diversity technology resulting in significant improvements in network performance and dramatic improvements in spectral efficiency, while at the same time lowering signal and noise levels.

To increase and improve the use of spectrum, CMRS operators must continue this trend of lowering their operating noise floors to meet the growing demand for voice and data services. This is particularly true for high-speed data services, which require substantially more margin over the interference noise floor than voice services. For network-based E911 location services, these CMRS systems will also be required to utilize signals that are much closer to the noise floor, and at multiple base stations for accurate location triangulation and determination.

For these reasons, unlicensed opportunistic easements and interference temperature concepts should not be applied to CMRS spectrum. With the very low noise conditions existing in CMRS spectrum today (and with trends expecting to lower noise levels further), there is no room for additional easements from unlicensed devices, and any transmissions from unlicensed devices can only lead to an increase in the operating noise floors in these bands, and impede existing and future services in these CMRS spectrum bands.

C. Typical Noise Levels in CMRS Spectrum are Significantly Below Peak Levels

In Figure 1 of the Interference Temperature NOI,[14] the FCC depicts opportunity for unlicensed devices to use spectrum up to the maximum (peak) level that exists in the network, while implying this will not cause interference to incumbent licensed radio systems. This assumption is critically flawed for the CMRS spectrum bands. In CMRS systems, the noise and interference levels are not correctly depicted in the FCC's Figure 1, and the systems are not designed to overcome peak noise levels occurring in their networks.

The FCC's exhibit incorrectly portrays the typical interference noise floor conditions existing in today's CMRS systems. In these systems, the peak (maximum) noise levels are

[14] FCC Interference Temperature NOI, Page 7, Figure 1.

significantly above the typical noise levels occurring for the vast majority of the day, and peak levels occur very infrequently. As shown below (in Table 1, and Figures 1 through 4 at the end of this section), the peak noise is statistically insignificant and occurs less than 0.02% in many cases (less than 20 seconds per day); 99.98% of the time the operating noise floor in CMRS systems is considerably lower (typically 20 dB lower than the peak level). Therefore, the peak noise levels are not representative of typical operating conditions in CMRS systems.

The results of the cellular and PCS noise studies conducted by V-COMM were utilized for this analysis. Included below, the CMRS system "noise levels vs. time" are shown for two locations from the PCS noise study, and the "noise levels vs. probability" are shown for two cell sites from the AMPS cellular noise study. These cases include urban, suburban and rural environments, and are representative of other locations and sites surveyed in the spectrum noise studies. These field measurements show the *actual* noise and interference conditions existing in CMRS networks, and show a very different picture than the FCC's Figure 1.

In CMRS systems, the operating noise levels are heavily concentrated at very low noise levels (very "quiet" noise conditions) for the vast majority of the measurements. The system's noise and interference levels are very low (-127 to -129 dBm) for the vast majority of the time (81% to 97%).[15] Compared to these typical operating conditions, the peak levels are significantly higher and not characteristic of normal conditions occurring in CMRS networks.

Furthermore, CMRS systems are not designed to overcome maximum (peak) noise conditions, rather they tolerate it at reduced quality levels for only brief moments of the day (i.e.

[15] For the locations depicted in Figures 1 and 2, 97% of the time the system's noise levels are in the range -127 to -129 dBm. For the cell sites depicted in Figures 3 and 4, they are in the range of -127 to -129 dBm, 81% and 95% of the time, respectively. Further, the noise levels are at the lowest readings (i.e. at or below -129 dBm) 76% and 88% of the time, for the locations depicted in Figures 1 and 2.

10-20 seconds). Quality of service levels are maintained on these networks because the noise and interference remains at very low levels for the vast majority of the day (i.e. 81% to 97% of the time).

If an "interference temperature" limit was set *at* the peak noise level, as suggested in the NOI, the maximum peak noise condition would occur *all* the time. If this happens in CMRS spectrum, it will wreak havoc on the networks and cause complete system outages in many cases. The noise floor would increase substantially (i.e. on average 20 dB), which is significantly more (worse) interference than studied in the Network Impact Study (Section VI) of this report, and it would result in catastrophic harm to the CMRS networks. In the Network Impact Study, the case study of a permitted external interference at the same level of the system noise floor (increases the total cumulative noise floor by 3 dB) results in significant harm to the CMRS system. For these reasons, the system noise levels in CMRS spectrum (peak or typical levels) must never be used as guides for "interference temperature" limits.

Band	System	Test #	Test Location	Market Type	Peak Noise Above Typ.	Peak Noise % Time	Peak Noise Secs/day	% Noise Below Peak
PCS	TDMA	10	Philadelphia, PA	Urban	10 dB	0.015%	13 sec	99.985%
PCS	TDMA	2	Lehigh, PA	Rural	22 dB	0.027%	23 sec	99.973%
Cellular	AMPS	13	Delaware, PA	Suburban	19 dB	0.018%	16 sec	99.982%
Cellular	AMPS	15	Montgomery, PA	Rural	28 dB	0.022%	19 sec	99.978%
				Average:	20 dB	0.02%	18 sec	99.98%

Table 1 Peak Noise Levels in CMRS Spectrum

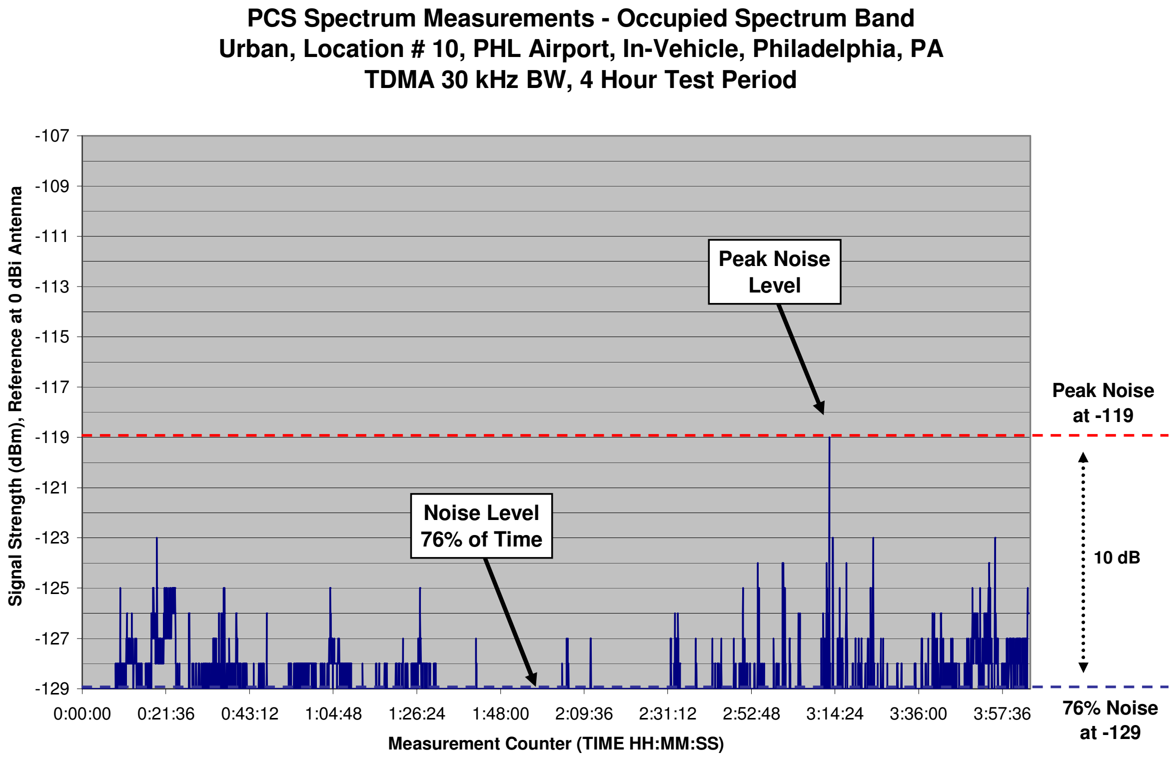

Figure 1 PCS Noise Study, Urban, Location #10, Noise Levels vs. Time

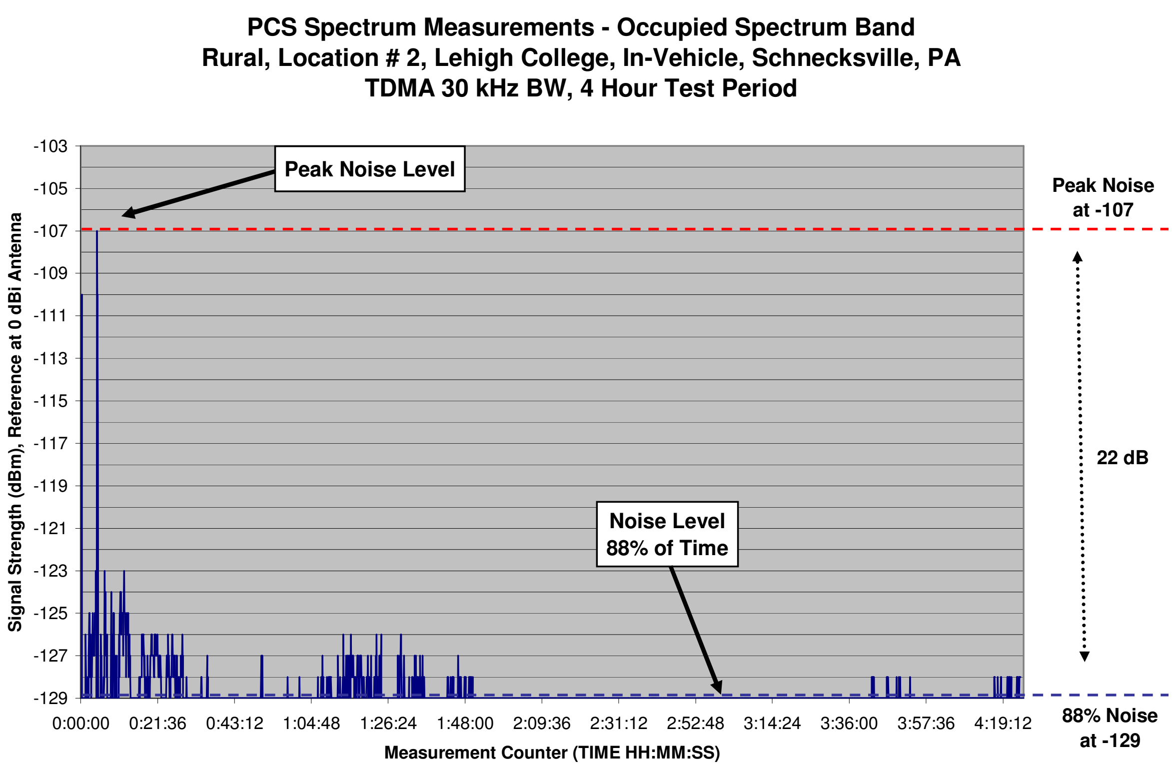

Figure 2 PCS Noise Study, Rural, Location #2, Noise Levels vs. Time

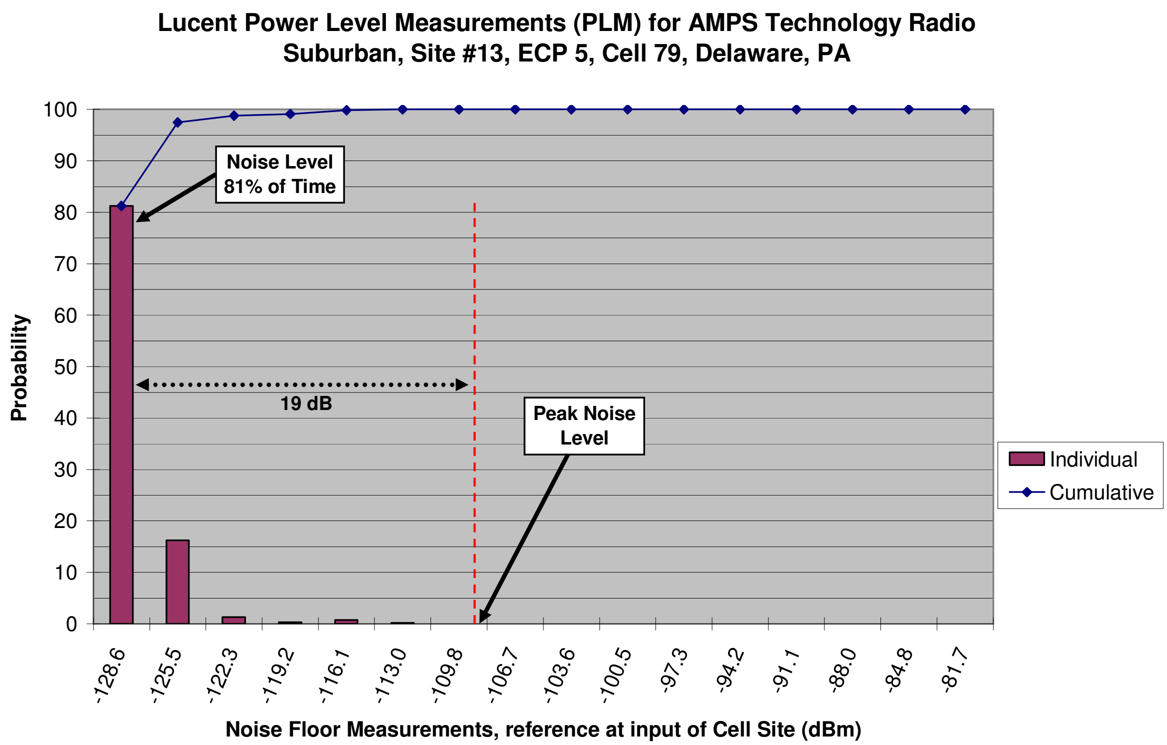

Figure 3 Cellular AMPS Noise Study, Suburban, Site #13, Noise Levels vs. Probability

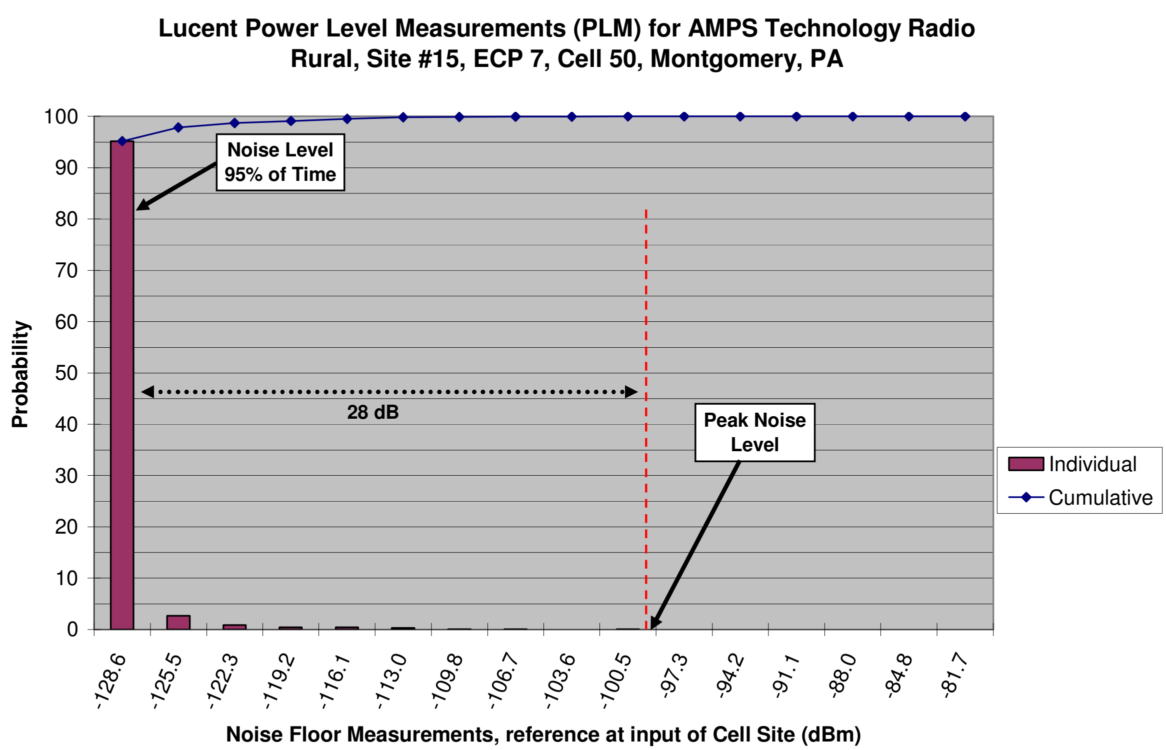

Figure 4 Cellular AMPS Noise Study, Rural, Site #15, Noise Levels vs. Probability

IV. MAJOR TECHNICAL FLAWS OF INTERFERENCE TEMPERATURE CONCEPT

Within the Interference Temperature NOI, the Commission seeks comments regarding the adoption of a quantitative standard, the "interference temperature" concept, to manage and improve the use of radio spectrum. The FCC's concept proposes to establish a maximum interference limit that would allow new spectrum-sharing users to co-exist within previously occupied bands of spectrum.

As addressed herein, the FCC's Interference Temperature concepts should not be applied to existing and future licensed CMRS spectrum for a variety of reasons. The concepts do not offer protection against the effects of harmful interference for existing licensed services operating within these spectrum bands. If applied to CMRS spectrum, the operating noise levels would increase in these bands causing harmful interference to these networks and thereby reducing the value of CMRS spectrum.

There is no room for easements below the existing use of CMRS spectrum, and therefore the FCC's interference temperature concepts are incompatible with CMRS spectrum bands. Any introduction of new uncontrolled, unlicensed entrants will result in an increase in the system noise floor and negatively impact cellular and PCS networks. The difficulties in applying this concept to the CMRS bands arise from the fact that these bands are currently one of the most intensively used frequency bands in the electromagnetic spectrum. The CMRS bands have the highest density of users, and highest mobility of users. The FCC's Spectrum Policy Task Force Report acknowledges that high density, high mobility, and increased flexibility offered to cellular make such bands unsuited for applications of these spectrum-sharing concepts.

One premise for the use of the interference temperature metric is the assumption that interference and noise floors have increased over time.[16] This is not correct for the cellular and PCS bands. Intuitively, the addition of more transmitting cell sites within a particular frequency band would be expected to increase the noise floor of that band. In practice, however, for reasons outlined below, CMRS bands have experienced a "quieting effect" to their operating noise levels over time. The CMRS industry has actively managed its spectrum, which has allowed operators to improve spectrum efficiency and meet market-based needs for more capacity and better coverage and quality of service. The noise and interference levels have been steadily decreasing over time, and will continue to approach the thermal noise floor should the spectrum remain "exclusive". In these bands, noise and interference floors have decreased as a result of network optimization and improvements (antenna down-tilts, power control, and many other features), and with the introduction of technology advances like digital cellular. For example, with CDMA technology, the system controls the power of emissions 800 times a second to the minimum power level required to maintain service, keeping system noise levels to an absolute minimum. As a result, these systems can operate under noise-limited conditions again, which has not occurred since cellular began in the early 1980s. Systems employing GSM technology have also seen similar benefits with advanced power control algorithms, adaptive rate vocoders, discontinuous transmission, frequency hopping and improved antenna diversity technology resulting in significant improvements in network performance and dramatic improvements in spectral efficiency, while at the same time lowering signal and noise levels. This is how cellular/PCS systems have improved spectrum efficiency and significantly increased their subscribers for the past 20 years (*i.e.,* by using technological advances to lower both

[16] FCC's Interference Temperature NOI , Paragraph 15.

interference and desired signal levels, instead of increasing signal levels to overpower noise). The only way to allow this evolution in technology and spectrum efficiency in CMRS bands to continue is to maintain these bands as "exclusive", and not allow the spectrum to be shared with opportunistic devices.

Sharing these bands with unlicensed devices will result in an increase in the operating noise floors in these bands and degrade system coverage, capacity and quality of service. When the noise floor increases, the performance of the network decreases, as does the utility of the spectrum. This runs contrary to the FCC's goal of increasing/improving the use and utility of spectrum. As such, the FCC's interference temperature concepts should not be applied to CMRS spectrum. The conceptual and major technical flaws with the FCC's "Interference Temperature" model as they apply to CMRS spectrum are explained in the following sections.

A. The Interference Temperature Concept Is Not Proven Science

The Interference Temperature concept proposed in the FCC's Interference Temperature NOI is not proven science. The concept is unproven theory, it is untried and does not have demonstrated experience. It is not based upon scientific study or academic research. It was first conceived by the FCC's Spectrum Policy Task Force, and did not exist beforehand in literature or science. At this point, it should be considered in the same category as unsubstantiated and unproven science. Accordingly, the FCC should be extremely cautious in considering and relying upon unproven concepts before making sweeping changes to the way it manages spectrum, which will have implications for hundreds of millions of wireless users for the foreseeable future. "Proof of concept" testing and comprehensive testing with actual market conditions must be addressed prior to rules changes, to ensure existing licensed services are protected from the ensuing interference. Complicating matters is the fact that the unlicensed devices are uncontrolled devices by their very nature (they can operate at very close distances to victim receivers). Neither the licensed operator nor the FCC will be able to control the devices once they are released into mass circulation; and the potential for harmful interference would not be controllable either. Adding to the problem is the quantity of the devices, which contributes to the increase in the operating noise floor in the spectrum band. The density of the unlicensed devices is not considered by the FCC's Interference Temperature proposals. If such devices are mass-marketed and proliferate as widely as cordless phones and Wi-Fi devices, each cell site in a CMRS network will, at any given time, have to contend with hundreds of unlicensed devices actively transmitting at unknown locations on the operator's supposedly exclusively-licensed frequencies.

Other basic components are not considered either. The Interference Temperature concept does not consider the effects of the distance of the unlicensed devices from victim incumbent receiver (nor the power level of the unlicensed devices). The received interference level is dependent on distance from unlicensed transmitter to the victim licensed receiver, however the distance between these devices cannot be controlled or managed. Hence, the interference limit cannot be controlled either; it will vary considerably, increasing the closer the devices are to the incumbent licensed receivers. No such mechanism can be enforced that would allow them to maintain safe operating distances, and as the devices approaches the incumbent licensed equipment, their transmissions will raise the noise and interference levels at the incumbent's receivers.

For these reasons and others provided in the next section, the FCC's Interference Temperature concepts are significantly flawed. Also, should unlicensed devices be allowed to co-exist in licensed spectrum, the harm would be permanent. There are no mechanisms for removing such unlicensed devices once millions of them are permitted to share-spectrum. Therefore, the FCC should not apply these concepts to CMRS spectrum bands, which already have high density, high mobility and high utility of spectrum use. Rather, the FCC should ensure the protection of the CMRS services as a first priority, and allow these spectrum bands to remain "exclusive".

B. Major Technical Flaws of Interference Temperature

In the Interference Temperature NOI, the FCC proposes an "interference temperature" model, whereby a maximum level of external interference is permitted from unlicensed devices in licensed spectrum bands, based upon the radio environment within the licensed bands. Such a model is significantly flawed and not practical for applications in licensed CMRS spectrum bands. If applied, the noise and interference levels in these bands would significantly increase and would cause significant and uncontrollable harmful interference to the incumbent licensed CMRS spectrum users. The major technical flaws of the FCC's Interference temperature concepts are explained below, specifically addressing applications in CMRS spectrum.

1. Unlicensed Devices will Increase Operating Noise Floors – Any transmissions from spectrum-sharing devices in CMRS spectrum will increase the operating noise floors in CMRS networks. The power levels received at the victim incumbent receivers from all nearby spectrum-sharing devices will add to the existing system noise floor, and the total cumulative noise floor would increase for the system. Even external interference as low as 20 dB below the CMRS system operating noise floor will result in a 1% increase in the total cumulative noise floor (interference 30 dB below, will result in an 0.1% increase). To limit the impact to cellular/PCS systems, the external noise levels received at the victim receivers would have to be substantially lower than the existing operating noise floors, and at these low levels no spectrum sharing system could effectively operate. Therefore, there is no limit that

would allow their systems to operate and at the same time provide sufficient protection from harmful interference to cellular/PCS.

2. CMRS Systems are Not Designed to Overcome Highest Peak Noise Levels Occurring – In Figure 1 of the Interference Temperature NOI,[17] the FCC's exhibit incorrectly portrays the interference noise floor for a typical CMRS system, and incorrectly presumes that CMRS systems are designed to overcome the highest-peak noise level occurring within its system. In CMRS systems, the highest peak noise levels are much higher than the noise levels occurring for the majority of the day, and peak noise levels occur very infrequently. The peak levels are statistically insignificant and occur less than 0.02% in many cases (about 20 seconds per day), and 99.98% of the time the operating noise floor in CMRS systems is considerably lower (typically 10 to 20 dB lower than the peak level occurring).[18] And, should the Commission adopt an "interference temperature" limit *at* the maximum measured interference level in CMRS spectrum, it will cause significant harmful interference to licensed spectrum users. This proposal seems contrary to what is expected of the Commission, which is to strive at improving the efficiency of spectrum use, and attempt to improve (lower) the noise floor, which would allow increased use of spectrum. Instead of taking the worst-case environment and adopting it everywhere, all the time, it would be better to improve and extend the best-case interference (lower noise floor) environment.

3. The "Signal to Noise Margin" in CMRS Spectrum is used by the System - The Interference Temperature concept assumes that the "margin" above the prevailing noise and interference level is not used by the system, and that it is essentially available for other unlicensed devices to use, but his is not true for cellular/PCS spectrum. In this spectrum, it is used to provide coverage at quality services levels to users at the edge of the cell sites, to provide capacity for users of CDMA and GSM frequency hopping systems, to provide high-speed data for broadband data services offered, and most importantly it is used to provide coverage/service to in-building cell phone users, which represents a large and growing percentage of users in

[17] FCC Interference Temperature NOI, Page 7, Figure 1.

[18] Refer to the Spectrum Noise & Interference Studies section of this report for the peak to average noise levels occurring in typical CMRS systems today. Actual field measurements should always be considered for these analyses. The FCC should not rely upon textbooks, outdated measurements, or other studies that are not verified by the operator.

CMRS spectrum.[19] Further, the FCC should recognize that the typical operating noise floors in CMRS systems are significantly lower than the maximum level, and licensed spectrum users *do* take advantage of the spectrum at these times, which results in improved spectrum access at lower signal levels. The licensed carriers should be able to fully utilize their spectrum. If someone else is using it, they will not be able to.

4. "Interference Temperature" Will Increase Noise and Interference Floors and Cause Harmful Interference – Should interference temperature concepts be applied to CMRS spectrum, the additional transmission from many unlicensed devices will increase the operating noise floors in the band and cause harmful interference to incumbents. The increasing noise floors will cause decreasing coverage areas resulting in increased "dead zones" for voice and data services; decreased data throughput , decreased quality of the service (reduced MOS and BER), decreased capacity of calls handled by the system leading to obstructions/blocking of service, degradation in system performance/quality of service, and can interfere with E911 location-based technologies , as mandated by the FCC, resulting in incorrect locations being sent to public safety entities resulting in possible loss of life situations.

5. "Interference Temperature" Will Degrade E911 Performance – The signals from devices that raise the operating noise and interference floor above the minimum can disrupt E911 location-based technologies used by carriers to comply with FCC mandates, resulting in incorrect locations being sent to public safety entities and resulting in possible loss of life situations. In such systems, very weak signals from mobile units are monitored from numerous cell sites, not just the serving cell site, in order to determine the mobile's location with a high level of accuracy. These signals may be well below the levels ordinarily expected at the serving cell site for an acceptable-quality call. Accordingly, an uncontrolled transmission from an opportunistic device that senses no signal above the interference temperature threshold could literally obliterate the signal needed to triangulate an emergency caller's location. Under such circumstances, licensed network operators would not be able to maintain the FCC-required location accuracy levels.

[19] V-COMM has observed substantial decreases in system performance for AMPS, TDMA and CDMA systems in compatibility interference tests conducted and submitted in the AirCell spectrum-sharing proceeding (ET 02-86). In these interference tests, the increase external interference causes a loss in

6. Differences in Receiver Location and Characteristics Will Prevent Proper Measurement of Interference Temperature – Unlicensed opportunistic device will not be able to measure the interference temperature *referenced* to the victim licensed receiver. It can only measure it *referenced* to its own receiver and from its own *location*, and the noise floor conditions at another location may be very different. With the nature of radio propagation, noise and interference levels will vary considerably from one location to the next. This is due to a variety of reasons including the distance from the transmitter source, multi-path signal fading, penetration through walls, partitions, buildings, foliage, and other factors. Multi-path fading can vary signal and noise levels by up to 30 dB over very short distances (i.e. less than one wavelength), and building and wall penetration can vary signals by 10 to 30 dB, depending signal paths through walls or windows. In addition to differences in location, receivers can have different receiver characteristics including bandwidth and noise figures, different detector circuits, and they can utilize different antennas, orientations and polarities. All these factors contribute to a very different noise level measured from one location on one receiver as compared to another. Consequently, the "interference temperature" cannot be measured as proposed. The opportunistic device will only measure the interference temperature for its own receiver at its own location, which can be very different from the actual noise and interference floor experienced by the incumbent licensed receivers.

7. Cannot Distinguish Signals from Interference – Another major technical flaw is that the opportunistic device will <u>not</u> be able to measure and distinguish the *interference* levels from incumbents the "primary signals" on the system (the signals; not the interference). Such a device will simply determine whether the received noise levels at its location exceeds some predetermined threshold, whether that level consists of thermal noise, environmental noise, licensees' primary signals, managed intra-system interference, or unmanaged external interference. And, neither will they distinguish transmissions from other opportunistic devices sharing-spectrum, nor inter-modulation products created within the measurement device itself. When these cases occur, the opportunistic devices may incorrectly assume the interference temperature limit can be set significantly higher than the victim network's actual

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signal margin, loss in quality (BER, FER & MOS), loss in system capacity, loss in system coverage, and loss in quality of service (increased blocked and dropped calls) for the network.

noise and interference level, and cause significant harmful interference to the incumbent system.

8. Ever-Increasing Noise Floor Condition – the interference temperature limit can result in an ever-increasing system noise floor. In this scenario, when spectrum-sharing devices increase system interference levels and incumbent licensed systems increase their signal levels to overcome this additional interference, the incumbent's *internal* system interference levels will increase. This in turn may increase the interference temperature limit set by the Commission or by network monitoring devices (due to increased interference levels present), which allows the spectrum-sharing devices to increase their power, and the entire process continues, until one system runs out of power or both systems are defeated.

9. Overbuilding Networks is Expensive and Not Efficient Use of Spectrum – Should licensed operators overbuild their networks to accommodate the increase in noise floors due the external interference from unlicensed devices, the impact can be severe in terms of build-out efforts and dollars (as shown in the Network Impact Study section of this report). In addition, this leads to a decrease in spectrum efficiency, higher prices for consumers, and removes the incentives for operators to deploy innovative technology in the future.

10. The Harm to Licensed Bands Would Be Permanent – If unlicensed devices are allowed to proliferate by the millions and share CMRS spectrum, it would cause significant harmful interference to CMRS operations. And, with no mechanisms to remove these devices from the market, the harm would be permanent. Unlicensed devices by their very nature cannot be removed from the market once put into circulation.

11. Establishing an Interference Cap Will Remove Operator Incentive to Deploy Advances in Technology – Another problem inherent with establishing an "interference temperature" limit, is that there would no longer be an incentive for licensed service operators to develop and deploy advanced technologies that reduce system interference and more efficiently utilize spectrum. Technology advancements have involved improving and lowering internal system noise floors to achieve improvements in spectrum efficiency. There are many examples of these CMRS technologies, as explained below. Consequently, by establishing this interference "cap", it would stifle advances in technology and pose significant limits on future spectrum use for incumbent licensed carriers.

12. Other Factors that Represent Major Problems – The density of these unlicensed devices, the distance from victim receivers, and the transmitter power level of the external unlicensed devices are very significant. Within short distances and with multiple devices, significant variation in received power levels can occur at the victim incumbent receivers. With the unlicensed "commons" approach these factors cannot be controlled or managed by either the Commission or the incumbent carriers, and thus they will lead to harmful interference to CMRS networks.

Examples of CMRS technologies and network operations that have reduced system interference levels are outlined below.

- Advanced Power Control Algorithms – Advanced power control algorithms have reduced system interference levels to an absolute minimum. In CDMA systems, the power control algorithm adjusts the power level 800 times per second in 1 dB increments, to serve calls at the lowest power required to maintain call quality. In W-CDMA (UMTS) systems the power control rate is 1500 times per second.
- Advanced System Features – With GSM technology and other technologies, the systems reduce system interference levels with forward & reverse link power control, discontinuous transmission algorithms, adaptive rate voice coders, and frequency hopping systems.
- Soft Handoff and Improved Diversity Algorithms – In CDMA systems, soft handoff and RAKE receiver systems allow base stations and phones to operate at reduced power levels (which reduces system noise levels), due to combining of multiple signals.
- Lower Transmit Power Levels for Base Stations and Mobiles – In mature CMRS systems, base stations typically utilize lower transmit power settings to maintain system performance, thus reducing noise levels in the system. The transmit power levels for mobile phones have decreased over the years, as well, from 3 watt car phones, to portable phones with 600 mW (AMPS & TDMA phones), to 200 mW for CDMA phones. Typical operating power levels for phones has also decreased considerably with power control algorithms based on call quality thresholds (i.e. typical transmitting power levels for CDMA phones are about 1 mW). Lowering the transmit power levels has created

lower noise levels within the system, and has improved spectrum efficiency. Further, as more sites have been added to the system to support capacity and coverage penetration demands, this further allows systems to consistently lower transmit power levels, which lowers the operating noise floor in the band.

- In-Building Wireless Phone Usage – In-building wireless phone use has increased substantially over the years. This trend is expected to continue, and results in significantly lower interference levels within CMRS system, due to the attenuation of signals and noise levels as they pass through the building structures.

The lowering of system interference levels has allowed increased service areas, particularly for in-building phone users, provided increased network capacity to meet demands for service, and allowed high-speed data services to be delivered by the system. These trends are expected to continue into the future with advanced third and fourth generation CMRS technologies lowering system interference levels further and utilizing spectrum more efficiently. Establishing an interference temperature "cap" will discourage CMRS service providers from deploying these advanced technologies and improving spectrum efficiency.

C. Internal vs. External System Interference

In the FCC's Spectrum Policy Task Force Report, the Task Force refers to interference and noise floor levels without distinguishing between *internal* system interference and *external* interference.[20] For CMRS service providers and other incumbent licensees, these types of interference are vastly different. Internal system interference is under control of the service

[20] *Internal* system interference refers to a CMRS system's co-channel and adjacent-channel emissions existing in markets from its base stations and callers, in addition to the background noise levels present. This is the "interference plus noise" of the system. *External* interference refers to transmissions from unlicensed spectrum-sharing devices that are not part of the CMRS system (they are external to the system).

provider while external interference cannot be controlled, managed or mitigated in any way by the provider.

As CMRS systems grow and markets mature, CMRS providers have numerous techniques and methods to continually manage their system's (internal) interference levels. The CMRS service providers' radio frequency (RF) engineering coordinators and performance monitoring staff employ these techniques on a regular basis to maintain and mitigate internal system interference.[21] These techniques include:

- Designated frequency assignment per base station coverage area, where the RF engineer consistently maintains and re-tunes its network to optimize performance and mitigate the system's co-channel and adjacent channel interference levels.
- Down-tilting antennas, lowering antenna heights, deploying narrower horizontal beam-width antennas, and other adjustments to reduce the reception of system's internal interference levels.
- Reducing base station and mobile transmit power levels, and utilizing diversity receive antenna systems reduce the surrounding internal interference levels to allows base stations and mobiles to complete calls at lower received signal levels.
- CMRS system settings can minimize the effects of internal interference through the use of handoff and access protocols that keep the mobile phone communicating with the closest base station, thus minimizing the interference each caller observes.
- Underlay / Overlay (dual) cell configurations,[22] which allows closer frequency reuse for frequencies used within the inner rings. This technique allows service providers to maintain calls requiring lower noise floors on outer ring coverage areas.
- Advanced frequency assignment techniques using flexible (dynamic) frequency assignments,[23] where the system knows which channels are used at nearby base stations, and avoids those channels that are active in those nearby base stations.[24]

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[21] Internal system interference primarily consists of the co-channel and adjacent channel interference received from neighboring base stations and mobile phones.

[22] Dual-cell configurations are utilized in some AMPS, TDMA and GSM wireless systems.

External interference is quite different. Licensed service providers and their customers do not have any control or ability to manage or mitigate this type of interference. The source of the external interference is extremely difficult to detect and monitor on an ongoing basis. In contrast, CMRS service providers have the ability to detect and control their internal system interference levels with frequency planning tools and system performance tools. The licensed operator knows the co-channels and adjacent channels used within its own network, and it can make adjustments accordingly. External interference, on the other hand, cannot be controlled by the licensed operator; it is controlled, if at all, by the external system, which manages its operations to benefit its own coverage and performance requirements.

In today's systems, CMRS operators have deployed digital technologies which are not inherently more robust than other technologies against external interference. While these technologies incorporate error-detection and correction features and other techniques for countering intra-system interference, the primary reason for deploying digital technologies is to increase network capacity and quality of service. With multiple voice conversations digitally "stacked" onto the same channels as before, the digital signals are *less* robust than analog technology with respect to external interference. Within the CMRS industry, an example of this is the deployment of digital technology (TDMA 30 kHz), which is an upgrade of the analog (AMPS 30 kHz) technology. In upgrading from AMPS to TDMA, some service operators noticed a slight increase in the required carrier-to-interference ratio for acceptable quality service, i.e. from 17 dB to 18 dB. With digital signals sharing the same channel, all of the "robustness" of the digital technology was used to provide additional capacity and none was

[23] Flexible frequency assignment techniques are utilized in some TDMA and GSM wireless systems.

[24] This flexible frequency assignment is not performed with scanning and sensing equipment, rather it knows which channels are in use from internal system information provided by the CMRS switch.

reserved for additional interference protection. Further evidence of this is verified in V-COMM's controlled interference tests conducted at an AMPS and TDMA base station.[25] It was noted that TDMA digital technology was more sensitive to blocked and dropped calls than AMPS technology, exhibiting blocking and dropping at an injected external interference level that was 6 dB lower (more sensitive) than AMPS analog technology.

CDMA digital spread spectrum technology is similar. In CDMA systems, approximately 20 to 35 users are sharing the same radio channel, and the same channel is used in every cell site and sector. The robustness of the CDMA technology was optimized to increase capacity and coverage for CMRS systems, and not for additional rejection of external interference. In CDMA systems, the system is power-controlled 800 times a second to within 1 dB of the lowest power that is capable of providing service.[26] With this tight system power control, the internal system noise of the CDMA system is kept to an extremely low level, with signals operating very close to the thermal noise floor.[27] With these very low signal levels, CDMA systems are very sensitive to external interference. Even when external interference is received at or below the noise floor of a CDMA system, it will be received at similar or stronger signal levels than the CDMA traffic signals, and will cause harmful interference.

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[25] V-COMM conducted base station interference tests at a TDMA and AMPS base station, in conjunction with an AirCell compatibility test program, and was submitted to the Commission on April 10, 2003, in the AirCell proceeding (ET 02-86).

[26] CDMA systems adjust power levels in 1 dB increments at a rate of 800 times per second (for uplink IS95 systems, and for uplink and downlink 3G1X systems), to maintain calls at the lowest operating power levels that provide acceptable voice quality.

[27] CDMA signals operate as low as the base station receive sensitivity level, i.e. -124 dBm, well below the noise floor levels at -109 dBm (kTB=-113 dBm, Noise Figure =4 dB), given EbNo=6 dB and Processing Gain=21 dB. CDMA signals have the ability to operate at, and below the thermal noise floor of its receivers due to the inherent processing gain of the system. This processing gain is used to provide capacity for the system, and not as an interference margin for external systems, as deployed in military applications. In Cellular and PCS CDMA systems, there is no margin reserved for external system interference.

In addition, CDMA systems have internal controls to manage its internal system interference, and have signal characteristics designed to allow the system to mitigate the effects of the non-desired user signals over the desired user signal. In this way, it optimizes the use of its spectrum and lowers the system's interference to provide coverage and capacity to its subscribers. Any external interference would increase the noise floor of a CDMA system and cause decreased coverage, capacity and/or service quality.

It should be noted that during the transition from analog to digital, some CDMA operators learned the hard way that the spectrum used for CDMA technology had to be cleaned of any existing AMPS channels within the CDMA carrier and guard band, and other external interference. Teams of engineers drove around the initial systems with spectrum analyzers and direction finding antennas looking for interferers that degraded the initial CDMA networks. They also learned that the adjacent cell sites had to be cleared of AMPS co-channels two and three cells away to insure optimum performance. Today, CDMA operators routinely request neighboring systems to clear the adjacent cell sites of channels in the proposed new CDMA carrier to ensure performance and operation of the new CDMA carrier channel. Only by identifying and controlling the system's internal interference and adjacent market interference are the CDMA operators able to maintain acceptable system performance.

Future technologies also hold promise for mitigating the *internal* system interference levels. Technologies such as joint detection, multi-user detection, and interference cancellation can effectively remove system interference because the statistical characteristics of the signal are well known to the systems. With these advanced technologies, systems can operate under noise-limited conditions; however, any external interference will not be able to be removed. Should unlicensed operations be permitted to share cellular spectrum, there would not be an incentive to deploy these advanced receiver technologies. For this reason, the internal system interference should never be used as a guide to set the interference threshold, or temperature, for cellular spectrum.

Regarding the impact of external noise on CDMA systems, Lucent has investigated this effect on reverse-link system coverage and quality, in a document submitted in the FCC Spectrum Policy Task Force report proceeding.[28] In Appendix A of its comments, Lucent quantifies the effects to CDMA (IS95) system coverage and capacity based upon external interference at a static (fixed) level. V-COMM agrees with Lucent's analysis and recommends the Commission consider these harmful effects to CDMA systems. In addition, harmful effects to CDMA quality of service (Blocked & Dropped Calls, Poor Voice Quality) can be expected with dynamic or transient sources of external interference. V-COMM agrees with Lucent's conclusion that "external interference will negatively impact the capacity and coverage of CDMA systems."[29]

In Lucent's analysis, an external interference power equal to the noise level of a CDMA receiver (assumed -109 dBm for base stations) will cause a significant decrease in system coverage and capacity (in the range of 30% to 80%), and even an external interference power of -120 dBm, or 11 dB below a CDMA receiver's noise level, will decrease system coverage and capacity in the range of 4% to 6%.[30] These levels of external interference represent harmful interference to CDMA networks.

[28] Lucent Technologies' comments are submitted in the ET Docket No. 02-135 proceeding, on Jan. 27, 2003.

[29] Lucent Technologies' comments submitted Jan. 27, 2003, Annex A, Section 4, Summary.

[30] Lucent Technologies' comments submitted Jan. 27, 2003, Effect on Reverse Link Coverage and Capacity Sections.

In summary, internal system interference is quite different than external interference. The external interference is not under control of the primary licensee's system, and any increase in the noise floor observed by the licensed spectrum user will result in a loss of coverage, capacity, and/or quality of service.

For these reasons the Commission should not permit additional external interference with levels greater than or lower than existing interference levels in CMRS spectrum bands. Using the existing interference level as the "interference temperature" limit would lead to an increase in the spectrum noise floor, cause deterioration in CMRS service and discourage service providers from deploying more spectrally efficient technologies in the future.[31]

[31] Most improvements in spectrum efficiency involve lowering internal system operating noise levels and utilizing signals closer to the noise floor. Establishing a fixed noise level would prevent service providers from the ability to improve their use of the spectrum in the future.

V. MAJOR TECHNICAL FLAWS OF COGNITIVE RADIO CONCEPTS

In response to the FCC's proposal to utilize Cognitive Radio Technology as an enabling technology to share-spectrum, V-COMM would like to echo statements made by the CTIA, Qualcomm and Arraycomm submitted in the FCC's Spectrum Policy Task Force Proceeding. From the CTIA, statements include these "technologies are still currently in the development stages, and at present time have not proven either technically or economically viable…should not be positioned as a spectrum management panacea."[32] Also from Qualcomm, "it is unlikely that [it]… will be implemented in commercial equipment", and "it is impossible with today's technology for the radio to sense the impact that its operations will have on the operations of another radio. The radio cannot 'hear' another receiver."[33] Also from Arraycomm, "Such a technology would require major technology advances in RF components to be feasible at all, and additional manufacturing and technology advances to be feasible at consumer price points and form factors."[34]

V-COMM would like to reiterate these points in this FCC proceeding and state that it would not be sound spectrum policy to rely on undeveloped, unproven technology to meet the goals of increasing the use of licensed spectrum. At this point, Cognitive Radio Technologies should only be permitted in existing and future CMRS spectrum under strict control by licensed operator, thus allowing the service provider to control and prevent harmful interference to the network. This allows the licensed operator to fully utilize the spectrum for its use, with

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[32] CTIA submitted comments, Jan. 27, 2003, Pg. 12, in FCC's SPTF Report proceeding (ET 02-135).

[33] Qualcomm submitted comments, Jan. 27, 2003, Pg. 3-4, in FCC's SPTF Report proceeding .

[34] Arraycomm submitted comments, Jan. 27, 2003, Pg. 11, in FCC's SPTF Report proceeding.

flexibility to use it to the fullest extent possible, and for secondary market applications (spectrum leasing).

A. Cellular & PCS Spectrum Bands Are Heavy Utilized By Incumbents

Cellular and PCS spectrum bands are heavy utilized by the incumbent license holders and contain very little “white space,” or unused spectrum. It is well known that the use of cellular phones has exploded in the past decade and additional services such as wireless Internet access and text messaging continues to increase the demands placed on cellular and PCS provider’s spectrum allocations. Despite the heavy demands on system capacity, cellular and PCS providers have continued to support significant growth in usage. To meet this demand for service, cellular and PCS providers have deployed advanced digital technologies, improved system performance and engineering, and expanded their networks, which have allowed them to increase capacity and improve spectrum efficiencies in their bands.

The cellular bands have been and continue to be one of the most utilized bands in the electro-magnetic spectrum. With a high density of base stations (162,000 nationally) and cellular users (159 million nationally), and high mobility of users, these spectrum bands operate at very high utilization levels. As can be observed in Figure 5 and Figure 6 below, the cellular spectrum bands show significant utilizations from a spectrum study conducted by the NTIA (National Telecommunications and Information Administration) in 1995 at two sites in San Francisco, CA. These spectrum plots show the high utilization of cellular systems in 1995, with high operating levels (see “maximum sample” and “mean sample” levels) for both the forward and reverse cellular spectrum bands at both locations measured, which are substantially above the background noise levels measured (“minimum sample”). As can be expected, the use of cellular spectrum has is increased dramatically since 1995, and today the spectrum is operating at much higher utilization levels.

For example, V-COMM observed the use of cellular spectrum in Cranbury, NJ, which is within a suburban market area in the cellular New Brunswick, NJ Metropolitan Statistical Area (MSA) market (also New York Major Trading Area or MTA). The cellular spectrum bands were recorded in March of 2004, using an HP 8594E spectrum analyzer and a mobile antenna for the cellular band. These recordings show the level of activity (spectrum use) of the standard cellular A and B bands.

In Figure 7 below, an operational cellular system employing GSM, TDMA and AMPS technologies can be observed in the cellular A band (Cingular Wireless). Within the spectrum, it is observed that GSM technology is utilizing frequency hopping carriers between 871.5 and 876 MHz, and the true density of the spectrum is not apparent as only a small fraction of the carriers are captured in a single sweep. In frequency hopping systems, both the intended transmitter and receiver have prior knowledge of the frequency hopping sequence. Any cognitive radio opportunistic devices, which do not have access to this knowledge, will not be able to “fit in” between the random GSM frequency hopping carriers.

In Figure 8 below, an operational cellular system employing CDMA and AMPS technologies can be observed in the cellular B band (Verizon Wireless). Within the spectrum, six CDMA carriers can be observed in the center of the spectrum plot, each having a carrier bandwidth of 1.25 MHz, and AMPS control and voice channels can be observed at either end of this spectrum. This figure clearly shows that CDMA cellular systems utilize a very dense modulation, with no “white space” between the CDMA carriers.

It is our experience that these spectrum plots are representative of other suburban areas of the country with spectrum being used intensively by the system, and even higher utilization of spectrum activity can be expected in more urban areas. As the demand for usage grows, additional carriers are expected to be added to this spectrum, further increasing the density and use of spectrum. As these figures illustrate, significant carrier energy is concentrated throughout the allocated spectrum. With both the CDMA spread-spectrum and GSM frequency hopping systems, the systems are designed to utilize the full set of spectrum frequencies at every cell site. This allows the cellular and PCS providers to provide a highly efficient communications system within their limited spectrum allocation, and leaves very little or no “white space” in the frequency, spatial or time domains for opportunistic cognitive radio unlicensed devices. In addition, with the continued growth in the cellular usage, as well as emerging voice and data applications, it can be expected that the utilization of cellular spectrum will further increase and the availability of white space in this spectrum to be virtually non-existent.

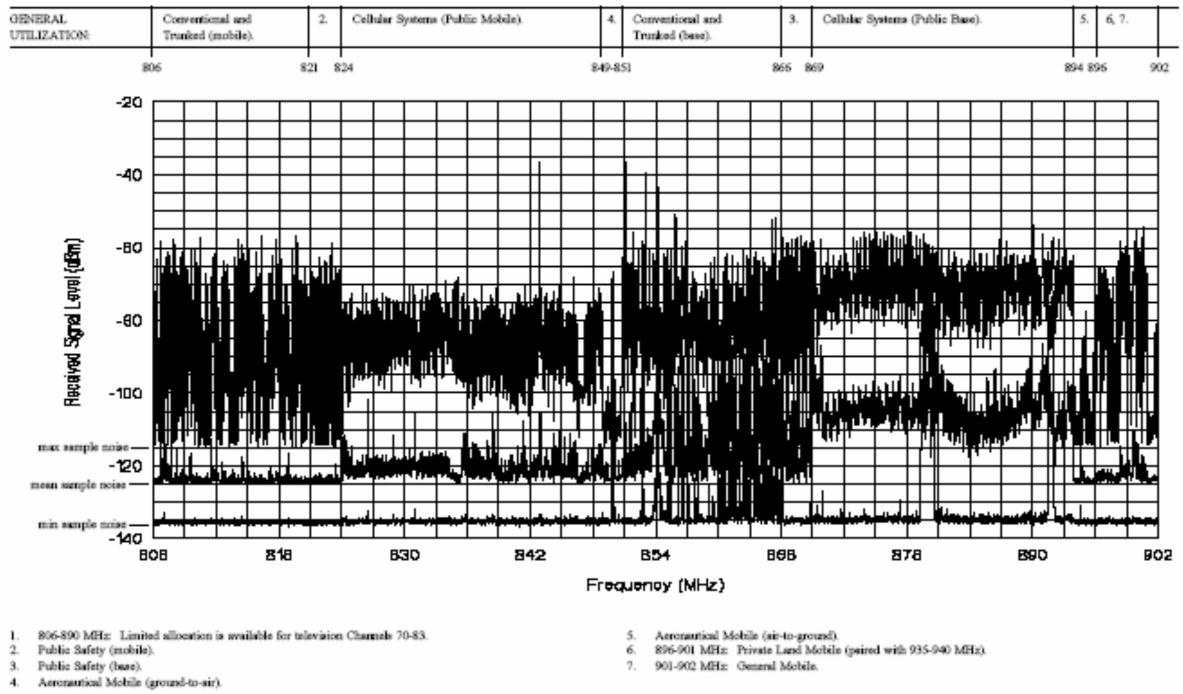

Figure 29. NTIA spectrum survey graph summarizing 2,880 sweeps across the 806-902 MHz range (System-1, band event 22, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Francisco (Grizzly Peak), CA, 1995.

Figure 5 NTIA Spectrum Survey, Figure 29 of NTIA Report 99-367

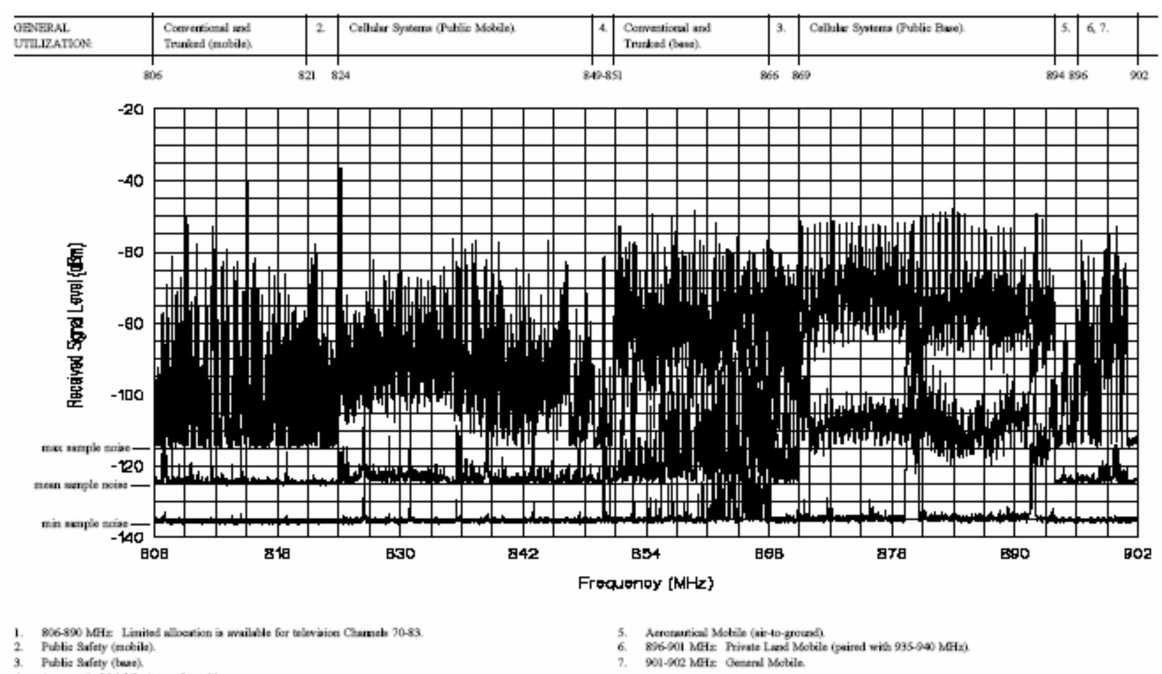

Figure 30. NTIA spectrum survey graph summarizing 3,300 sweeps across the 806-902 MHz range (System-1, band event 22, swept/m3 algorithm, sample detector, 10-kHz bandwidth) at San Francisco (Yerba Buena), CA, 1995.

Figure 6 NTIA Spectrum Survey, Figure 30 of NTIA Report 99-367

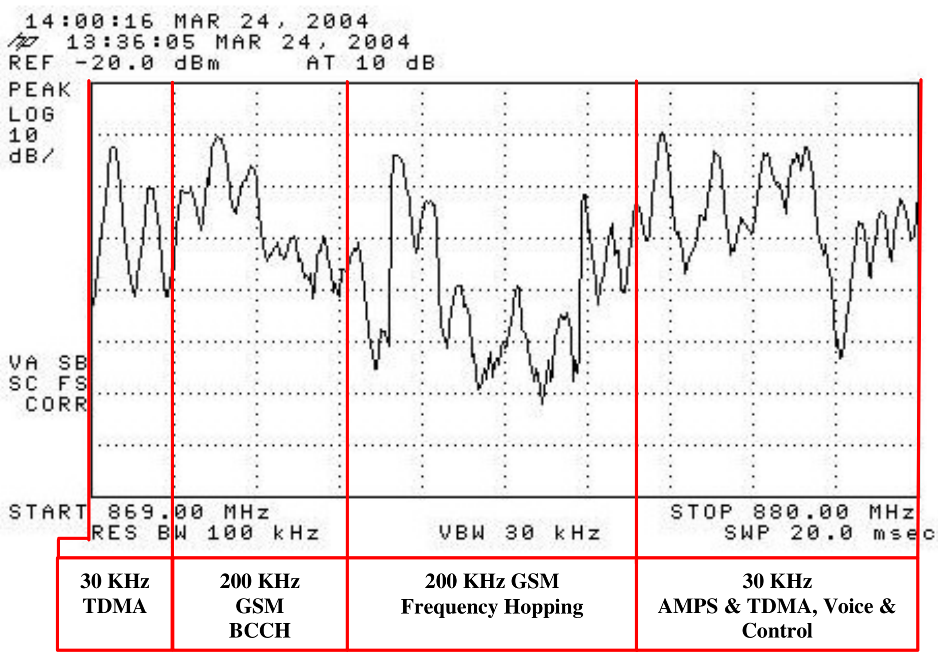

Figure 7 Cellular A Band Spectrum (March 2004, Cranbury, NJ)

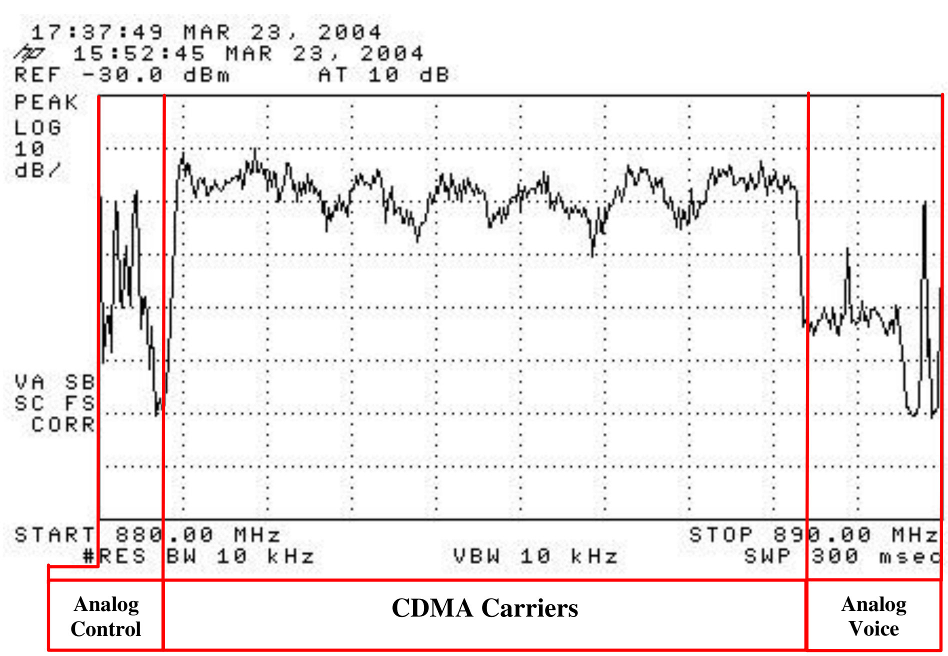

Figure 8 Cellular B Band Spectrum (March 2004, Cranbury, NJ)

B. Cognitive Radio Concepts Will Cause Harmful Interference to Incumbents

The FCC's "Cognitive Radio Technology" concepts are technically flawed, overly simplistic, and will not protect CMRS spectrum users from harmful interference, should these concepts be permitted by the FCC to be used by unlicensed opportunistic devices in licensed CMRS spectrum. From a layperson's standpoint the concept may appear reasonable, but in practical engineering terms and real-world circumstances, the concept will cause problems for licensed CMRS spectrum users. The concept would result in many "false positives" for spectrum-sharing devices that transmit due to incorrect assessments of spectrum availability. These examples include the following:

1. Receiver Location – There is no solution for the "hidden node problem", as many others have indicated in the FCC's Spectrum Policy Task Force proceeding. Since the location of Cognitive Radio sensors and victim licensed receivers are not the same, sensors are only able to read the radio environment for their immediate vicinity or location, as seen on its receiver and on its antenna. The unlicensed cognitive radio will not be able to sense the radio environment with respect to a different location, or receiver, and the radio environment can drastically change with respect to location. It can vary considerably by location to location, depending on a number of factors including: distance from transmitters, multi-path signal fading, penetration through walls, partitions, buildings, foliage, and other factors. Any signal path obstruction or signal penetration can easily result in a false determination of spectrum availability. This scenario is depicted in the diagram below (Figure 9). In this case, the sensory devices will not be able to detect the transmission from the CMRS base station, due to the signal path blockage and penetration through structures in the local environment. In this case, the forward (cell to phone) spectrum channel would appear unused, as measured by the sensory scanning receiver, however it is actually in-use by a nearby licensed spectrum user. When the spectrum-sharing device transmits, it can cause harmful interference to the licensed incumbent spectrum user.

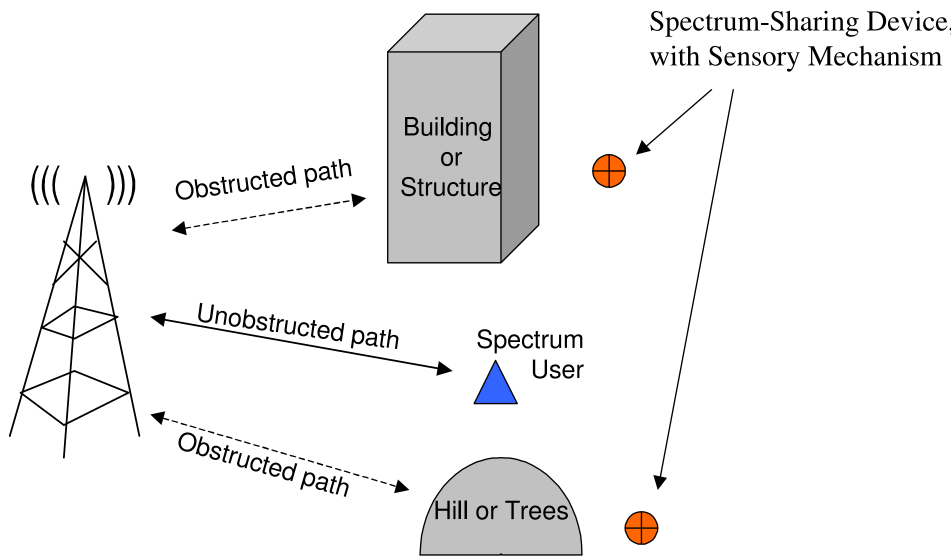

Figure 9 Obstructed signal paths to sensory devices cause incorrect assessment of spectrum availability

Another situation causing harmful interference is a spectrum-sharing Cognitive Radio device that is out of range of the base station signal, as depicted in Figure 10 (below). Due to the range of the signal path from the base station to the spectrum-sharing device, the device would not receive sufficient signal strength and would interpret this as a false opportunity for spectrum sharing. In this case, the spectrum would *appear* unused, as measured by the scanning receiver, however it is actually in-use by a nearby licensed spectrum user. When the spectrum-sharing device transmits, its signal will be received by the primary spectrum user and cause harmful interference.

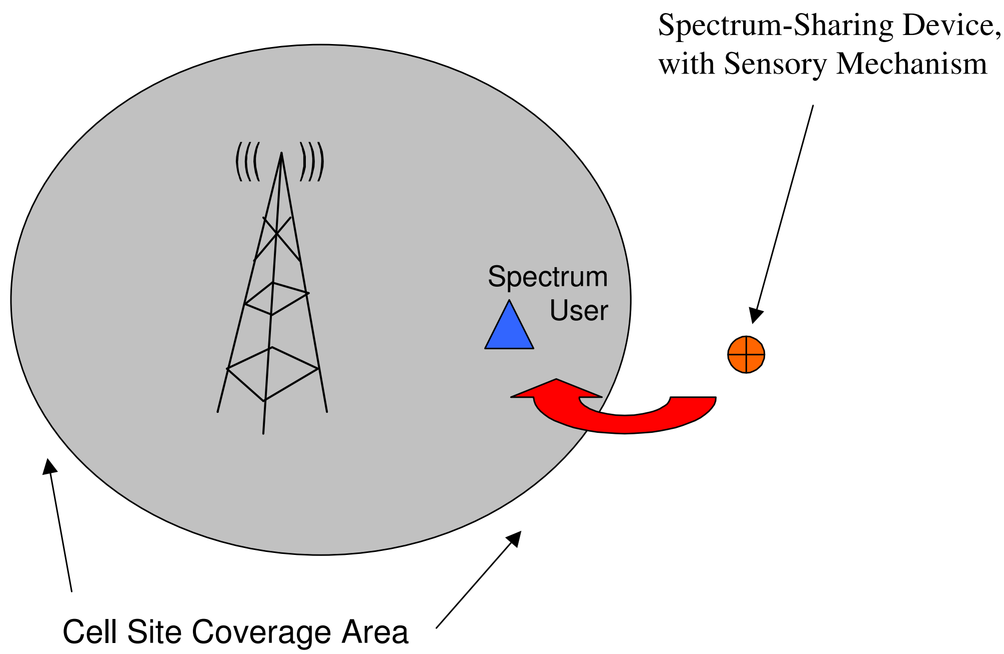

Figure 10 Sensory device out of range of base station coverage area causes incorrect assessment of spectrum availability, upon transmitting, causes interference to mobile station

2. Cell Site Forward vs. Reverse Spectrum Bands - Another compatibility issue with Cognitive Radios spectrum-sharing device is with measurements of cell site reverse-link (phone to base station) vs. forward-link (base station to phone) bands. A spectrum-sharing device that is measuring the reverse-link spectrum would not be able to detect far-away mobile signals (and assume the spectrum is unused), however the spectrum can be in-use with the cell site antennas able to use signals from far-away mobile subscribers. Upon transmitting on the reverse spectrum band, the spectrum-sharing device can be received by nearby base stations, increase their noise floors, and cause harmful interference.

3. Many Other Factors - In addition to the three examples described above, there are numerous other examples that would result in similar "false positive" indications of spectrum availability, due to other differences in the spectrum-sharing device and primary spectrum user's system.

a. Location - the spectrum-sharing device may be located within buildings, urban canyons, coverage holes and other locations that cannot detect spectrum use, but can cause interference to nearby licensed spectrum users.

b. Antenna - the spectrum-sharing device may have different antenna types, gains, orientations, polarization and location than the primary spectrum user. This results in a different signal level and noise floor level for the device, as compared to that experienced by the "victim" spectrum user's antenna.

c. Receiver - the spectrum-sharing device may have different receiver characteristics, including resolution bandwidth, detector circuits, noise figure, sensitivity and technology than the licensed spectrum user. These would all contribute to a different signal and noise measurement at the spectrum-sharing sensory device, as compared to the "victim" spectrum user's receiver.

4. Sensing While Transmitting Problem - Another situation that would result in interference, is when the spectrum-sharing device detects an opportunity to use spectrum that is available, and while transmitting it is unable to detect that the primary spectrum user also has begun transmitting. Many devices would not be able to transmit and receive on the same frequency at the same time. Even devices that employ time division duplex (TDD) operation do not transmit and receive simultaneously. Even in this circumstance, failed system access attempts may occur, in addition to pieces of voice conversations being lost.

5. The FCC's Cognitive Radio concepts are incompatible with technologies used in CMRS networks – Current CMRS systems employ a number of intelligent technologies that utilize real-time measurements of the radio spectrum to improve the use of spectrum and provide coverage, capacity and quality of service to its customers. These technologies measure the real-time received signal levels on radio channels to optimize the use of spectrum, and utilize these measurements to prevent the use of radio channels experiencing interference above predefined thresholds. In these cases, the opportunistic spectrum-sharing devices will prevent the CMRS systems from using its spectrum, and will block and obstruct service for the licensed incumbent. For this reason, the FCC's Cognitive Radio concept that relies upon sensing and utilizing available spectrum is flawed and incompatible with technologies deployed in today's cellular & PCS networks. Examples of these CMRS technologies are:

interference detection & evaluation on call assignment or handover for TDMA (Interference detection on call assignment, HOBIT handover on BER), AMPS (Interference detection on call assignment, handoff on SAT SINAD) and GSM (interference on call assignment, handoff on BER); and CDMA system forward-link and reverse-link noise level overload control thresholds (which is required for system operation). These CMRS technologies and systems will block channels from use and obstruct service when transmissions from unlicensed devices are detected in its spectrum.

VI. NETWORK IMPACT STUDY FOR CELLULAR & PCS SYSTEMS

It is very important to consider the impacts on existing and future CMRS networks, and the tens of millions of current and potential subscribers, should the FCC decide to implement the Interference Temperature concept. As mentioned previously in this document, the CMRS industry and its service providers have been successful in continuing to post significant subscriber gains along with new features and advanced services over the past 20 years. These significant increases have been the direct result of the CMRS providers' ability to properly manage the spectrum which has been licensed to them. It is expected that these increases and advancements will continue, however, if the FCC allows harmful interference from unlicensed devices to pollute these bands, the service providers will either have to accept this interference and the reduced service levels that exist, or overbuild their networks to overcome this new level of uncontrollable interference. This study considers four scenarios of incrementally increased noise floors from external unlicensed devices to quantify this impact to CMRS networks.

This study is a conservative, high level estimate of the impact to cellular and PCS networks to accommodate the external interference from unlicensed opportunistic devices sharing CMRS spectrum. The coverage model effectively estimates the number of cell sites required to maintain service for pre-deployed CMRS systems, and underestimates the number of sites required for post-deployed CMRS system.[35] Also, the capacity model is conservative in that it does not include the effects of reduced trunking efficiency for available voice channels.

[35] In practice, overbuilding cell sites to a CMRS network will result in addition cell sites require to maintain service, due to multiple sites replacements/fill-ins to accommodate specific losses in coverage areas due the placement of the new sites (availability of locations, zoning, etc.).

Therefore, this model is a conservative estimate of the number of cell sites required to maintain service; in practice the impact to the network would be more severe.

The study also quantifies the additional capital and operating expenditures in the form of overbuilding the network, which would otherwise not be needed, except to overcome external interference and maintain current service levels. The study considers four cases of increased interference levels and the relationship of additional sites required in an overbuild scenario and the resultant network costs. From the results, we can see that the impact is very sensitive to the increases in interference or noise, and is significant even at low levels of interference (i.e. interference level at or below existing noise levels, with total cumulative noise increasing). Further, the impact increases exponentially with modest increases in noise power levels.

The model considers the capacity and coverage impact to cell sites in 3 environment categories: Urban, Suburban, and Rural. The model assumes that the impact to Rural areas is primarily a coverage issue, in that increased noise translates into decreased coverage areas for rural sites. Urban areas are assumed to have capacity primarily impacted and Suburban areas have an even split between coverage and capacity when additional noise is permitted in the network. Based upon experience in market analysis and cell site deployments, V-COMM estimates the cell site breakdown for Urban, Suburban and Rural is 37%, 34% and 29% respectively. Further, based upon extensive experience in engineering wireless networks and review of industry accepted propagation modeling tools, V-COMM estimates the propagation loss per market for Urban, Suburban and Rural areas at 35, 32 and 29 dB per decade, respectively. The coverage and capacity impact model relies upon formulas and methods supplied by Lucent which have been filed in the FCC's SPTF Report proceeding.[36] In our study, the Lucent model was utilized with the path loss characteristics for each market type, and its capacity model was utilized for a wireless CDMA network using 3G-1xRTT and IS95 (2G, EVRC vocoder) technologies in equal proportions.

The model also assumes the noise increase due to external interference is at a static and consistent level across the network of cell sites. With this model, as developed by Lucent, the impact to coverage is independent of the technology deployed in the CMRS network (essentially equating to loss in link margin due to increased external interference),[37] and would apply to both the cell site forward and reverse links. The capacity effect is based upon CDMA technology for the cell site reverse link in this study. The capacity and coverage models, as developed and used herein, apply to CMRS systems operating in either cellular or PCS frequency bands (i.e. it is frequency independent).[38] The model shows the percent increase as manifested by the number of cell sites required to maintain coverage and capacity on the systems, as a result of external interference increasing the operating noise floor in CMRS spectrum. Within the model, V-COMM uses estimates for network costs which are based upon industry experience and also publicly available information for the Verizon Wireless network.

[36] Lucent's report was filed on January 27, 2003, within the public comment period of the FCC's Spectrum Policy Task Force (SPTF) Report proceeding (ET 02-135). Within Appendix A of the report, Lucent provides analyses that describe and explain the derivation of formulas that model the impact to CMRS networks in terms of loss in coverage and capacity, due to external system interference. Lucent is a major manufacturer of CMRS network equipment, and has extensive experience and insight with respect to the operation and performance of cell site equipment and CDMA technology. In conclusion, the Lucent report states that the "external interference will negatively impact the capacity and coverage of CDMA systems." In its analysis, Lucent quantifies the impact to network coverage and capacity with respect to the level of external interference to the system.

[37] The coverage impact model is independent of technology, as it represents the loss in link margin of a signal. As such, the results of the coverage impact analysis are representative of CMRS systems employing CDMA, TDMA, GSM and/or AMPS technologies.

The model assumes a fixed interference level across all cell sites. Although, in reality the external interference increase would vary considerably across different ranges, locations, and time. It will be dependent on the distance, quantity of devices, antenna, and transmission power of the unlicensed transmitters, relative to the victim licensed receiver. In many cases the actual interference will result in noise levels that are significantly higher than those shown by the model, which in these circumstances, will result in complete service disruption to CMRS systems. Since the unlicensed opportunistic devices are uncontrolled by their very nature (the location(s) in which they will operate are not under control by the FCC or the incumbent operator), the received power from them will be uncontrolled, as well. To account for this uncertainty, operators would have to build their systems to the higher interference levels (i.e. case study with 3 dB increase in cumulative noise) to tolerate the varying external interference levels occurring.

As can be seen in Table 2 below, Case Study 1 assumes that the added external interference is 11 dB below the internal system noise floor (i.e. I/N is –11 dB) and the increase in Total Cumulative System Noise Floor level is only 0.33 dB. However, this seemingly insignificant increase in cumulative noise floor (1/3 of a dB) increases the system noise power level by 8%. Likewise, following this through to Case Study 4 demonstrates that the increase in System Noise Power Level increases exponentially to 100%, when the Total Cumulative System Noise Floor Level is increased to what seems to be a relatively insignificant 3 dB.

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[38] The network impact models for coverage and capacity are frequency independent, and are representative of the impact to CMRS systems operating both 800 MHz and 1900 MHz bands.

Impact Study	External Inteference (I) dBm	Internal System Noise Level (N) dBm	Permitted I/N External Interference to System Noise, dB	Total Cumulative System Noise Floor Increase (dB)	% Increase in System Noise Power Level (%)
Case 1	-120	-109	-11	0.33	8%
Case 2	-118	-109	-9	0.5	12%
Case 3	-115	-109	-6	1	26%
Case 4	-109	-109	0	3	100%

Table 2 External Interference Impact to the System Noise Floor of a CDMA Base Station

When taking this increase in system noise power level a step further and considering the coverage impact using the propagation losses per market type as mentioned previously, it can be can seen in Table 3 that the coverage can decrease by a significant 38% in rural areas and as much as 32% in urban areas. In addition, the impact to CDMA capacity is such that it will be reduced by as much as 61% in areas that need it most.

Impact Study	Total Cumul. Noise Floor Increase (dB)	Permitted I/N dB	Coverage Impact Reduction in Coverage, per Market Type			Capacity Impact Reduction in CDMA Capacity
			Rural 29 dB/dec	Suburban 32 dB/dec	Urban 35 dB/dec	
Case 1	0.33	-11	5%	5%	4%	5%
Case 2	0.5	-9	8%	7%	6%	8%
Case 3	1	-6	15%	13%	12%	16%
Case 4	3	0	38%	35%	32%	61%

Table 3 Impact to Cellular/PCS System Coverage and Capacity

Next, if the impacts to coverage and capacity are translated into percent increases of additional cells required to overcome these external system considerations, it can be seen in Table 4 that these impacts are substantial. In fact, the number of additional cells required for a 3 dB Total Cumulative Increase in System Noise Floor is approximately 1.5 times the number of cells just for coverage, and 2.5 times the number of cells to make up for needed capacity.

Impact Study	Total Cumul. Noise Floor Increase (dB)	Permitted I/N dB	Coverage Impact Cell Sites Req'd After Impact, per Market Type			Capacity Impact Cells Req'd After CDMA
			Rural	Suburban	Urban	
Case 1	0.33	-11	105%	105%	104%	105%
Case 2	0.5	-9	109%	108%	106%	109%
Case 3	1	-6	118%	115%	114%	119%
Case 4	3	0	161%	154%	147%	256%

Table 4 Cellular/PCS Cell Sites Required to Maintain Existing Service

Table 5, below, hypothesizes a wireless carrier with a total number of cell sites across the country in excess of 20,000. This number of cell sites is further broken down into three classes of areas and then the varying levels of noise is increased as per the four Case Studies, it can be seen in Table 5 that the number of additional sites required for one nationwide operator increases dramatically. The approximate 20,000 number increases to over 43,000 to handle the loss in coverage and capacity that would result from the increased noise floor. As seen in Table 6, this increase translates into as much as 111% more sites required, just to maintain current system levels of coverage and capacity. It should be noted that this does not include any additional sites required in the normal course of business continuing to support the aforementioned gains in subscribers and advanced features and services.

Impact Study	Total Cumul. Noise Floor Increase (dB)	Permitted I/N dB	Number of Cell Sites Req'd, per Market Type			Total Cell Sites Required in CMRS Network
			Rural 29%	Suburban 34%	Urban 37%	
Current System	-	-	5,945	6,970	7,585	20,500
Case 1	0.33	-11	6,258	7,337	7,984	21,579
Case 2	0.5	-9	6,462	7,535	8,245	22,242
Case 3	1	-6	6,994	8,155	9,030	24,178
Case 4	3	0	9,589	14,297	19,449	43,335

Table 5 Number of Cell Sites Required to Maintain Existing Service

Impact Study	Total Cumul. Noise Floor Increase (dB)	Permitted I/N dB	CMRS Network Impact Additional Cells Req'd	% Additional Cells Req'd
Case 1	0.33	-11	1,079	5%
Case 2	0.5	-9	1,742	8%
Case 3	1	-6	3,678	18%
Case 4	3	0	22,835	111%

Table 6 Additional Cell Sites Required to Maintain Existing Service

Finally, when taking into account the additional sites required to maintain the current system levels, the additional capital and operating expenditures must be considered. These financial considerations will have a direct impact on the service providers' ability to provide cost effective and competitive services in the wireless marketplace. Table 7 below shows the impact on a carrier' expenditures to maintain its current network service levels.[39] As can be seen in Table 7 below, under these assumptions a seemingly insignificant 0.33 dB increase in the cumulative noise floor throughout the system translates into an 18% increase in total costs.[40] Likewise, a 3 dB increase in total cumulative noise floor increases total costs to nearly 400% of current levels. While 0.33 dB and 3 dB seem relatively insignificant, increased operating costs

[39] For this analysis, V-COMM estimates capital expenditures at $2,000,000 on a cell site basis, and operating expenditures at $100,000 per cell site, per year (equipment depreciation is not included in this operating expenditure). V-COMM estimated operating and capital expenditures per cell site based on its experience in modeling network build out plans for wireless service providers and on publicly available financial and operating information for a single large carrier, Verizon Wireless, These costs include those related to the related physical plant, switching, interconnection and maintenance systems.

[40] It is assumed that the service life of the new cell site equipment will be 8 years. Therefore, the "total network costs" for the new cell site equipment equals the capital expenditures plus eight times the annual operating expenditures (provided as "8 Yr Total" in Table 7). The percentage increase in total network cost (provided as "% Increase in Total Costs" in Table 7), equals the total network costs ("8 Yr Total") for each of the cases studies divided by the operating costs to maintain the current system (operating costs times the number of existing cell sites).

by 18% to 390%, in a highly competitive market are not. In these situations, the increase costs which would be expected to be passed along to subscribers are significant.[41]

Impact Study	Total Cumul. Noise Floor Increase (dB)	Permitted I/N dB	Additional Network Costs Required CapEx ($Millions)	OpEx/year ($Millions)	8 Yr Total ($Millions)	% Increase in Total Costs
Current System	-	-	-	$2,050	16,400	-
Case 1	0.33	-11	$2,158	$108	$3,021	18%
Case 2	0.5	-9	$3,484	$174	$4,877	30%
Case 3	1	-6	$7,357	$368	$10,300	63%
Case 4	3	0	$45,670	$2,283	$63,938	390%

Table 7 Total Network Costs Required to Maintain Existing Service

Further, in today's systems, the impact to data services and technologies will have decreased system throughput, latency and reliability. For all data technologies (GPRS, EDGE, 1xRTT, EVDO), the throughput is primarily dependent on the link budget and the available signal to noise margin. It can be expected that the service areas providing high-speed data will decrease, corresponding to the coverage percentage decreases shown in the coverage impact model. For example, in market areas where operators provide high-speed (broadband) service, after the coverage is reduced, those areas will no longer provide broadband service. In addition, the throughput for data services can be expected to decrease, when the external interference increases the system's operating noise floor. For CDMA systems, the decrease in data throughput can be expected to be within similar ranges shown by this model's percentage

[41] To maintain existing service levels, the additional costs for a hypothetical carrier with 37.5 million subscribers is expected to increase by 2%, 3%, 6% and 36%, for the four cases studies herein, respectively. This assumes a subscriber pays on average $50 per month for service (CTIA Semi-Annual Wireless Industry Survey for Dec-03).

reduction in capacity,[42] which represents a major problem for CMRS network's data services offered. For example, a CDMA data session at an average data rate of 60 Kbps losing 60% of its throughput results in a proportionately reduced speed, or 24 Kbps. This reduced speed is now too slow for many web browsing and VPN applications to operate effectively. When high-speed data service customers experience reduced throughput; this essentially negates the incentive for customers to purchase these new technologies, and leaves no incentive for operators to deploy them either.

Since unlicensed devices are not controlled by their very nature (they can operate at very close distances to victim receivers) and there can be multiple devices all contributing to an increase in noise level as well, the increase in the noise levels to existing licensed systems are expected to increase beyond the 3 dB case study provided herein, which results in significant and substantial harm to the CMRS system. In addition, the harm would be permanent, since there is no mechanism to recall unlicensed devices once in mass circulation.

When network capital and operating costs are increased as a result of uncontrollable external interference, the inherent value of the spectrum is reduced. With external interference increasing operating noise floors in CMRS spectrum, the performance of systems will deteriorate and service operators would need to make additional investments in networks to mitigate the effects of the external interference. As demonstrated by the results shown in this section, the impact to the CMRS networks and costs associated with them are substantial. When network operators are faced with additional and substantial financial outlays to maintain the performance

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[42] The CDMA capacity impact model assumes the network supports IS-95 and 3G traffic in equal proportions, and the percentage reduction in capacity represents the loss in the number of effective channels to be used by the system for voice or data (CDMA voice channels, or individual 8 kbps primary/supplemental data channels). Accordingly, the loss in throughput for CDMA systems supporting

of their networks, the costs of providing service increase and the value of the spectrum decreases.

CMRS providers have made significant investments to their licensed spectrum over the last 20 years, all of which have increased capacity, coverage, quality, network services and functionality. If the FCC had previously allowed opportunistic devices to cause harmful interference by increasing the noise floor of this spectrum years ago, it would have significantly increased the risks associated with the cost of network deployments and new technology advancements. Digital technology transitions in CMRS spectrum may not have occurred due the increased risks associated with these substantial network investments. Likewise, as risks increase going forward, operators may be less likely to continue to invest in current or any future spectrum at such a robust rate, as the concern would be whether or not the risk would return any reward since certain variables are out of their control. In addition, these risks may translate to other spectrum bands anticipated for auction by the FCC and expected to be used with the same intensity as CMRS spectrum, one would expected that the value of these resources will be reduced at auction time.

Therefore, the models utilized herein and the four reasonable Case Studies outlined, demonstrate that the potential for substantial impact to CMRS providers and their tens of millions of subscribers is great, if the FCC were to adopt the Interference Temperature concept with the intention of allowing unlicensed opportunistic devices to occupy the CMRS spectrum.

IS-95 & 3G-1xRTT data will experience a loss in throughput that is comparable to the loss in capacity shown by this model.

VII. DETERMINATION OF HARMFUL INTERFERENCE

In the Interference Temperature NOI, the Commission requests comments regarding the determination of harmful interference to incumbent service providers. The FCC states that "it is essential to quantify harmful interference in order to develop specific interference temperature levels. Once a level of harmful interference is determined for a specific service, then an interference temperature limit can be set …"[43] The FCC requests comments regarding how much interference can be tolerated for given frequency bands before it is considered *harmful.*

In this regard, V-COMM would like to emphasize the importance of a clear *definition* of harmful interference, which is a requirement *prior to* the *determination* of whether an interference level is harmful or not. Without a clear understanding of the definition of harmful interference, the spectrum-sharing newcomers or incumbent service providers will not know their rights and responsibilities. They will not have enough information to assess and interpret external interference, to properly setup and perform system test measurements to confirm the existence of harmful interference, or to coordinate with others to resolve external interference disputes.

A key element of the definition is the *level of protection* for services provided within the spectrum bands (i.e. will 100% of current voice and data services in CMRS spectrum be protected). Without knowing the level of protection for services in spectrum bands, harmful determinations cannot be made, and thresholds for external interference levels cannot be derived. Accordingly, the definition of harmful interference must first thoroughly clarify and address the *level of protection* for existing and future services.

[43] FCC's Interference Temperature NOI (ET 03-237), page 12, paragraph 27.

The current definition of harmful interference does not clearly specify the *level of protection* for communication services, and for this reason it must be updated prior to consideration of any spectrum-sharing proposal. The current FCC definition is subject to broad interpretation, is not quantifiable and is outdated with respect to new services offered in CMRS spectrum. The definition of harmful interference contained in section 1.907 of the FCC Rules is "interference that … seriously degrades, obstructs, or repeatedly interrupts a radio communications service". The interpretation of this definition can be overly subjective and not clearly understood. It does not provide incumbents clarity regarding protection of services deployed, nor does it provide them certainty in making additional investments in network build-outs or innovative technologies. In addition, the current FCC definition does not provide clear answers regarding the following issues:

- What constitutes acceptable vs. unacceptable interference?
- What constitutes a "serious" degradation in service?
- How many "obstructions" or 'busy signals' are considered harmful?
- How many "interruptions" during calls, or dropped calls does a system have to endure before it is considered to be experiencing harmful interference?

These answers and others need to be addressed for licensed service providers to understand their rights and responsibilities, how to manage their networks, and understand the risks associated with making new investments and upgrades to their networks. The FCC's Spectrum Policy Task Force report also concurs that there needs to be a clear and exhaustive definition of spectrum rights and responsibilities for licensed and unlicensed spectrum users.[44] For these reasons, the definition of harmful interference needs to be quantifiable, objectively measurable with accepted industry practices and procedures, and clearly understood.

The definition of harmful interference needs to be more specific relative to the level of protection for services and system attributes. Also, it should be updated to reflect new services (e.g. data services) and system attributes (e.g. capacity to serve users) provided in CMRS spectrum bands. Again, the current definition is much too generalized, and does not provide a good measure of protection for these issues.

For CMRS spectrum, the following services and system attributes should be protected from harmful interference:

<u>CMRS Services Protected from Harmful Interference</u>

Voice Services – [These voice services include voice communications.]

- Coverage – loss in range of transmission or margin of signal
- Capacity – loss in the number of customers supported
- Quality of Service – a deterioration in service performance, including blocked or dropped calls, or voice quality degradation

Data Services – [These data services include data transmissions, standard & enhanced messaging, video, VoIP, data terminal sessions, Virtual Private Networks, web browsing, e-mails, games, and other multimedia services.]

- Coverage – loss in range of transmission or margin of signal
- Capacity – loss in the number of connections supported
- Throughput – reduction of the bandwidth or speed of data transmissions
- Latency – increased delay (waiting time) of data session
- Quality of Service – increased errors (not correctable) in data transmissions

[44] FCC's Spectrum Policy Task Force Report, Pg. 18.

Location Services – [These location services include locates for E911 emergency calls, and other location services provided by the CMRS carrier.]

- Coverage – loss of in range of transmissions or margin of signals, used to perform locate services
- Quality of Service – reduction in location determination or accuracy

It is essential that modern communication services receive sufficient protection from the effects of harmful interference. This will establish regulatory and market certainty going forward, knowing that additional services deployed beyond standard voice technologies will be protected. In consideration of these issues, with regard to spectrum-sharing unlicensed devices, the definition of harmful interference should consist of similar language:

> Any measurable deterioration in the operation or performance of services offered by licensed carriers.

With regards to the communication services outlines above, examples of harmful interference to CMRS systems can be described as follows. For system coverage, harmful interference is the loss in transmission range or margin of signal necessary to sustain a CMRS service. The direct effect of a spectrum-sharing system is an increase in the spectrum noise floor, which has the potential to reduce the margin of signal and detection of signal at the primary system's receivers. For system capacity, harmful interference is the loss in the system's ability to provide services to customers. For example, in CDMA systems, an increase in the effective noise floor would reduce the number of users that can utilize the spectrum for its communications. Since CDMA signals operate below the thermal noise floor,[45] they are particularly sensitive to increases in the noise floor, and any increase has a direct and immediate

[45] CDMA signals have the ability to operate below the thermal noise floor of its receivers due to the inherent processing gain of the system. This processing gain is used to provide capacity for the system,

impact. For quality of service, harmful interference would be exhibited as dropped calls, blocked calls, or a reduction in the quality of voice, data or location services. For data services, harmful interference is a decrease in data throughput, reliability, or an increase in latency; these are the system attributes of data services. For location services, harmful interference is a decrease in location determination or accuracy. For network based location solutions, additional base stations are required to receive signals closer to the noise floor with lower signal margins to triangulate and determine location. For handset based solutions using assisted GPS technology, the mobiles will need to measure interference-free GPS and base station signals very close to the spectrum noise floors, in addition to using CMRS spectrum. Interference to these measurements would affect the accuracy of location services. In summary, increases in spectrum noise floors would have a direct impact to these services and system attributes, and must be defined as harmful interference.

In addition to updating the definition, the Commission should conduct a comprehensive review of the operating noise floors in spectrum bands to better understand the environmental noise levels, prior to the consideration of acceptable levels of interference from external spectrum-sharing systems.

In consideration of an updated definition, the FCC should also be cognizant of local market requests for improvements in network services,[46] the utility provided by the spectrum band to the American public, and level of protection that will be provided to future services that may be deployed in the bands.

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and not as an interference margin for external systems, as deployed in military applications. In CMRS CDMA systems, there is no margin set aside for external interference.

[46] For example, the California 'Bill of Rights' seeks to improve services derived from cellular spectrum.

The FCC should be mindful of the interests of the American people that have come to depend on cellular service. These are approximately half the people in United States, a growing percentage of people converting landline telephones to wireless service, callers in distress and emergencies situations accounting for approximately 50% of 911 phone calls, government workers & public safety entities responding to emergencies and national homeland security situations. There are significant public benefits in preserving the existing wireless services, and the FCC must protect these services from harmful interference.

In addition, the same protection should be provided for the advanced wireless services being offered by CMRS carriers today and in the future, including high-speed Internet access and other advanced voice and data services.

VIII. CONCLUSION

For the foregoing reasons, V-COMM respectfully requests the Commission to take consideration of the comments addressed in this report, to conduct a comprehensive review of the radio spectrum environment and the compatibility issues involved in spectrum-sharing prior to adopting rule changes for any spectrum band, and not to proceed with Interference Temperature initiatives within existing or future licensed CMRS spectrum bands. The Commission must carefully and cautiously consider the effects that any new spectrum-sharing services will have on increasing spectrum noise floors and causing harmful interference to existing communication services. The Commission's objective to increase and improve use of radio spectrum must be carefully tempered against its primary goal of protecting licensed communications services from the effects of harmful interference.

Respectfully Submitted,

V-COMM, L.L.C.

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Sean Haynberg,
Director of RF Technologies
David Stern, Vice President
Dominic Villecco, President
3 Cedar Brook Drive
Cranbury, NJ 08512
(609) 655-1200

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APPENDIX A – COMPANY INFORMATION & BIOGRAPHIES

V-COMM is a leading provider of quality engineering and engineering related services to the worldwide wireless telecommunications industry. V-COMM's staff of engineers are experienced in Cellular, Personal Communications Services (PCS), Enhanced Specialized Mobile Radio (ESMR), Paging, Wireless Data, Microwave, Signaling System 7, and Local Exchange Switching Networks. We have provided our expertise to wireless operators in engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. Further, V-COMM was selected by the FCC & Department of Justice to provide expert analysis and testimony in the Nextwave and Pocket Communications Bankruptcy cases. V-COMM has offices in Blue Bell, PA and Cranbury, NJ and provides services to both domestic and international markets. For additional information, please visit V-COMM's web site at www.vcomm-eng.com.

BIOGRAPHIES OF KEY INDIVIDUALS

Dominic C. Villecco
President and Founder
V-COMM, L.L.C.

Dominic Villecco, President and founder of V-COMM, is a pioneer in wireless telecommunications engineering, with 22 years of executive-level experience and various engineering management positions. Under his leadership, V-COMM has grown from a start-up venture in 1996 to a highly respected full-service consulting telecommunications engineering firm.

In managing V-COMM's growth, Mr. Villecco has overseen expansion of the company's portfolio of consulting services, which today include a full range of RF & Network design, engineering & support; network design tools; measurement hardware; and software services; as well as time-critical engineering-related services such as business planning, zoning hearing expert witness testimony, regulatory advisory assistance, and project management.

Before forming V-COMM, Mr. Villecco spent 10 years with Comcast Corporation, where he held management positions of increasing responsibility, his last being Vice President of Wireless Engineering for Comcast International Holdings, Inc. Focusing on the international marketplace, Mr. Villecco helped develop various technical and business requirements for directing Comcast's worldwide wireless venture utilizing current and emerging technologies (GSM, PCN, ESMR, paging, etc.).

Previously he was Vice President of Engineering and Operations for Comcast Cellular Communications, Inc. His responsibilities included overall system design, construction and operation, capital budget preparation and execution, interconnection negotiations, vendor contract negotiations, major account interface, new product implementation, and cellular market acquisition. Following Comcast's acquisition of Metrophone, Mr. Villecco successfully merged the two technical departments and managed the combined department of 140 engineers and support personnel.

Mr. Villecco served as Director of Engineering for American Cellular Network Corporation (AMCELL), where he managed all system implementation and engineering design issues. He was responsible for activating the first cellular system in the world utilizing proprietary automatic call delivery software between independent carriers in Wilmington, Delaware. He also had responsibility for filing all FCC and FAA applications for AMCELL before it was acquired by Comcast.

Prior to joining AMCELL, Mr. Villecco worked as a staff engineer at Sherman and Beverage (S&B), a broadcast consulting firm. He designed FM radio station broadcasting systems and studio-transmitter link systems, performed AM field studies and interface analysis and TV interference analysis, and helped build a sophisticated six-tower arrangement for a AM antenna phasing system. He also designed and wrote software to perform FM radio station allocations pursuant to FCC Rules Part 73.

Mr. Villecco started his career in telecommunications engineering as a wireless engineering consultant at Jubon Engineering, where he was responsible for the design of cellular systems, both domestic and international, radio paging systems, microwave radio systems, two-way radio systems, microwave multipoint distribution systems, and simulcast radio link systems, including the drafting of all FCC and FAA applications for these systems.

Mr. Villecco has a BSEE from Drexel University, in Philadelphia, and is an active member of IEEE. Mr. Villecco also serves as an active member of the Advisory Council to the Drexel University Electrical and Computer Engineering (ECE) Department.

Relevant Expert Witness Testimony Experience:

Over the past five years, Mr. Villecco had been previously qualified and provided expert witness testimony in the states of New Jersey, Pennsylvania, Delaware and Michigan. Mr. Villecco has also provided expert witness testimony in the following cases:

- United States Bankruptcy Court

- Nextwave Personal Communications, Inc. vs. Federal Communications Commission (FCC) **

- Pocket Communications, Inc. vs. Federal Communications Commission (FCC) **

** In these cases, Mr. Villecco was retained by the FCC and the Department of Justice as a technical expert on their behalf, pertaining to matters of wireless network design, optimization and operation.

David K. Stern
Vice President and Co-Founder
V-COMM, L.L.C.

David Stern, Vice President and co-founder of V-COMM, has over 20 years of hands-on operational and business experience in telecommunications engineering. He began his career with Motorola, where he developed an in-depth knowledge of wireless engineering and all the latest technologies such as CDMA, TDMA, and GSM, as well as AMPS and Nextel's iDEN.

While at V-COMM, Mr. Stern oversaw the design and implementation of several major Wireless markets in the Northeast United States, including Omnipoint - New York, Verizon Wireless, Unitel Cellular, Alabama Wireless, PCS One and Conestoga Wireless. In his position as Vice President, he has testified at a number of Zoning and Planning Boards in Pennsylvania, New Jersey and Michigan.

Prior to joining V-COMM, Mr. Stern spent seven years with Comcast Cellular Communications, Inc., where he held several engineering management positions. As Director of Strategic Projects, he was responsible for all technical aspects of Comcast's wireless data business, including implementation of the CDPD Cellular Packet Data network. He also was responsible for bringing into commercial service the Cellular Data Gateway, a circuit switched data solution.

Also, Mr. Stern was the Director of Wireless System Engineering, charged with evaluating new digital technologies, including TDMA and CDMA, for possible adoption. He represented Comcast on several industry committees pertaining to CDMA digital cellular technology and served on the Technology Committee of a wireless company on behalf of Comcast. He helped to direct Comcast's participation in the A- and B-block PCS auctions and won high praise for his recommendations regarding the company's technology deployment in the PCS markets.

At the beginning of his tenure with Comcast, Mr. Stern was Director of Engineering at Comcast, managing a staff of 40 technical personnel. He had overall responsibility for a network that included 250 cell sites, three MTSOs, four Motorola EMX-2500 switches, IS-41 connections, SS-7 interconnection to NACN, and a fiber optic and microwave "disaster-resistant" interconnect network.

Mr. Stern began his career at Motorola as a Cellular Systems Engineer, where he developed his skills in RF engineering, frequency planning, and site acquisition activities. His promotion to Program Manager-Northeast for the rapidly growing New York, New Jersey, and Philadelphia markets gave him the responsibility for coordinating all activities and communications with Motorola's cellular infrastructure customers. He directed contract preparations, equipment orders and deliveries, project implementation schedules, and engineering support services.

Mr. Stern earned a BSEE from the University of Illinois, in Urbana, and is a member of IEEE.

Sean Haynberg
Director of RF Technologies
V-COMM, L.L.C.

Sean Haynberg, Director of RF Technologies at V-COMM, has over 14 years of experience in wireless engineering. Mr. Haynberg has extensive experience in wireless system design, implementation, testing and optimization for wireless systems utilizing CDMA, TDMA, GSM, AMPS and NAMPS wireless technologies. In his career, he has conducted numerous first office applications, compatibility & interference studies, and new technology evaluations to assess, develop and integrate new technologies that meet industry and FCC guidelines. His career began with Bell Atlantic NYNEX Mobile, where he developed an in-depth knowledge of wireless engineering.

While at V-COMM, Mr. Haynberg was responsible for the performance of RF engineering team supplying total RF services to a diverse client group. Projects varied from managing a team of RF Engineers to design and implement new a PCS wireless network in the NY MTA; to the wireless system design & expansion of international markets in Brazil and Bermuda; to system performance testing and optimization for numerous markets in the north and southeast; to the development and procurement of hardware and software engineering tools; to special technology evaluations, system compatibility and interference testing. He has also developed tools and procedures to assist carriers in meeting compliance with FCC rules & regulations for RF Safety, and other FCC regulatory issues. In addition, Mr. Haynberg was instrumental in providing leadership, technical analysis, engineering expertise, and management of a team of RF Engineers to deliver expert-level engineering analysis & reporting on behalf of the FCC & Department of Justice, in the Nextwave and Pocket Communications Bankruptcy proceedings.

Prior to joining V-COMM, Mr. Haynberg held various management and engineering positions at Bell Atlantic NYNEX Mobile (BANM). He was responsible for evaluating new technologies and providing support for the development, integration and implementation of first office applications (FOA), including CDMA, CDPD, and RF Fingerprinting Technology. Beyond this, Haynberg provided RF engineering guidelines and recommendations to the company's regional network operations, supported the deployment and integration of new wireless equipment and technologies, including indoor wireless PBX/office systems, phased/narrow-array smart antenna systems, interference and inter-modulation analysis and measurement, and cell site co-location and acceptance procedures. He was responsible for the procurement, development and support of engineering tools for RF, network and system performance engineers to enhance the system performance, network design and optimization of the regional cellular networks. He began his career as an RF Engineer responsible for the system design and expansion of over 100 cell sites for the cellular markets in New Jersey, Philadelphia, PA; Pittsburgh, PA; Washington, DC; and Baltimore, MD market areas.

Mr. Haynberg earned a Bachelor of Science degree in Electrical Engineering with high honors, and attended post-graduate work, at Rutgers University in Piscataway, New Jersey. While at Rutgers, Mr. Haynberg received numerous honors including membership in the National Engineering Honor Societies Tau Beta Pi and Eta Kappa Nu. In addition, Mr. Haynberg has qualified and provided expert witness testimony in the subject matter of RF engineering and the operation of wireless network systems for many municipalities in the state of New Jersey.

APPENDIX B – AMPS NOISE FLOOR STUDY

APPENDIX C – PCS NOISE FLOOR STUDY